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A

TEXT-BOOK

OF

MILITARY ENGINEERING,

FOR THE USE OF THE

CADETS OF THE UNITED STATES MILITARY ACADEMY.

PARTS II. AND III.

COMPRISING

SIEGE OPERATIONS AND MILITARY MINING, WITH AN APPENDIX
GIVING THE PRINCIPLES OF FORTIFICATION DRAWING.

BY

J. B. WHEELER,

PROFESSOR OF ENGINEERING AT THE U. S. MILITARY ACADEMY, AND
BREVET-COLONEL, U. S. ARMY.

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PREFACE.

THIS Text-book has been prepared for the use of the cadets pursuing their studies in the course of Fortification at the United States Military Academy.

All unnecessary allusion to details has been as far as possible avoided in the text, leaving these matters to be supplied by the instructor in the class-room.

The "theory of mines" used in Part III. is not the one ordinarily given in works upon Military Engineering, but is the one advanced by Prof. H. Höfer in his notes upon mining, which have been translated by Captain Chas. W. Raymond, U. S. Engineers.

It has been deemed advisable to add an appendix, explaining the method of "Fortification Drawing." I have been assisted in the preparation of this addition, by a translation of General Noizet's notes upon this subject, made by Lieut. D. C. Kingman, U. S. Engineers, and by valuable suggestions made by Lieut. Roessler of the U. S. Engineers.

To Lieut. Willard Young, U. S. Engineers, I am indebted for much assistance in preparing these pages for the press.

J. B. W.

WEST POINT, N. Y.,
January, 1883.

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MILITARY ENGINEERING.

PART II.

SIEGE OPERATIONS.

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CHAPTER I.

SIEGE–WORKS.

1. Siege.—A position which is strongly fortified and vigorously defended cannot be taken by open assault. The attacking forces are compelled to resort to the operations of **a siege.**

A siege is ordinarily composed of three parts, viz.:

1. **The investment.**
2. **The bombardment.**
3. **The regular approaches.**

Usually all three of these parts are employed, although it sometimes happens that only one of them is necessary; as, for instance, when the position is so situated that the attacking forces can completely isolate the besieged, and prevent all aid, either from supplies or reinforcements, reaching them. Under such circumstances, it becomes a question of time only as to when the besieged, reduced by famine, must surrender the position. This method is usually termed a **blockade.**

In some cases, fortified places have been reduced by **bombardment** alone. The attacking forces, possessing a superiority in artillery, being able by their heavy and unceasing artillery fire, to wear out the endurance of the besieged, to destroy the defences and the buildings occupied by the defenders, and to compel a surrender.

2. Investment.—The object of an **investment** of a fortified place, when a siege is undertaken, is to prevent the besieged from receiving reinforcements and supplies. As the siege is prolonged, the supplies are consumed, and the numbers of the defenders are continually reduced by casualties and by disease. The besiegers—on the other hand—receiving reinforcements and supplies, are able to continually bring up fresh troops to carry on their operations, and, finally, to overpower the besieged by mere force of numbers.

It is not always practicable to complete the investment. An incomplete investment has the effect of prolonging the siege, and in some cases, of causing a failure upon the part of the besiegers to gain the position.

It is recommended to always thoroughly invest the position, and to close all avenues of approach to the fortifications, if a successful result is to be expected in a reasonable time.

3. Bombardment.—The object of a **bombardment** is by means of a heavy artillery fire to injure the defensive works, blow up the magazines, destroy the bomb-proof shelters, and set fire to all houses and constructions within the line of works defending the position which can be burnt. This constant fire, during the night as well as the day, has the effect of wearing out the endurance of the troops, and of terrifying the non-combatants who may be within the works. A surrender will frequently be made to prevent further destruction of valuable property, and to avoid loss of life among the residents of the place.

4. Regular Approaches.—The object of **regular approaches** is to afford means by which the besiegers can get near enough to the fortifications to remove all obstacles in the way of an assault, and finally to render an assault practicable.

Since it is practically impossible for the besieged to move over the ground in front of a strong fortification without being protected from its fire, arrangements must be made to shelter them from this fire as they advance. The means ordinarily used in modern times are sunken roads, termed **trenches,** so located that they cannot be swept by the fire of the besieged. The mass of earth excavated from the trench is thrown over on the side toward the enemy's fire, and piled up high enough to shelter the men who walk in the trench. This mass may be formed into a parapet, and have its inner side protected by a revetment, or it may be left in the position the earth assumes when thrown into a heap.

5. Trench-work.—The trenches are divided, according to their uses and location, into **approaches** and **parallels**; according to the method of construction, into **simple trench** and **flying trench-work**, etc.

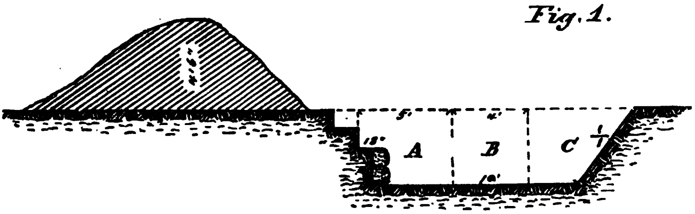
When the trench has a direction leading to the position to be taken, it is called an **approach**; if its general direction is parallel, or nearly so, to the front of attack, it receives the name of **parallel.**

An approach must be so directed that it cannot be swept by the fire of the besieged. This is effected by giving it a direction so that the line of trench, if prolonged, would pass outside of the points occupied by the besieged from which they could sweep the trench with their fire. The trench forming an approach is made to run in a zigzag direction, and each branch of the zigzag is so arranged as to be safe from an enfilade fire. From this arrangement, the approaches are frequently called **zigzags**, and sometimes, **boyaux**. The length of a branch depends upon the width of front allowed to the approach, and is usually limited to one hundred yards.

As the approaches are pushed forward, it becomes necessary to provide shelter for bodies of troops, who are used to support the working parties in the trenches, and to defend these parties from the sorties which may be made by the besieged. These shelters are obtained by extending trenches laterally on each side of the approaches. The trenches thus extended, are parallel, or nearly so, to the side of the fortification upon which the attack is to be made, and hence comes the name of **parallel** which has been given them.

6. **Simple Trench.**—The simplest kind of trench-work is the one called the **simple trench.** It is merely a sunken road with the earth taken from the excavation, and this earth piled upon the ground on the side toward the enemy. This method may be used for an approach, or for a parallel; and may have the mass of earth formed into a parapet, or left in a heap, as when thrown out. The working parties are necessarily exposed, in the beginning of its construction, to the fire of the besieged. And, as it will take nearly two hours from the time the soldier begins, until he has thrown up enough earth to give him cover from this fire, it follows that this method can be used only under favorable circumstances, and when the loss caused by the fire of the besieged is small.

Fig. 1.



The profile represented by Fig. 1, shows the section of a parallel constructed by the method of the simple trench.

The depth of the trench below the surface of the ground is taken as four feet, and the bottom is given a slope to the rear for drainage. Six inches will be sufficient for this difference, and will allow all the water in the trench to settle on the side farthest from the enemy.

The width of the trench should be sufficient to allow room for the troops stationed in it, and for those who will have to use it as a communication. The least width should not be less than ten feet at the bottom. The slope for the side in rear may be the natural slope of the earth, or less. The slope for the side next to the enemy may be as steep as the earth will take, or it may be arranged in steps. These steps should be given a tread of eighteen inches, and a rise not to exceed this amount.

The earth from the excavation is thrown out of the trench upon the ground on the side toward the besieged, and is piled up to a height of not less than four feet and six inches; a berme of two feet is left between the embankment and the trench.

It will be seen that, with these dimensions, troops moving in the trench are screened from the enemy's fire, and can, by standing on the berme, use the mass of earth as a parapet.

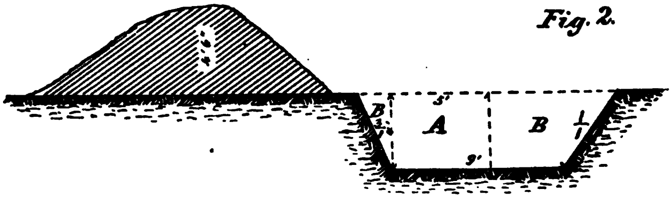


Fig. 2.

The profile represented by Fig. 2, shows the section of an approach constructed by the method of the simple trench.

The depth of the approach is taken to be the same as that given for a parallel.

The width at the bottom should not be less than nine feet, although it is as well to have it ten, if circumstances will admit.

Steps are not represented in this section, but they should be used if it be necessary for those troops in the approaches to mount quickly upon the berme.

For the purpose of drainage it is recommended to give a slope to the bottom of the trench.

Each branch of an approach should overlap the one behind it by about ten yards, to add to the protection against enfilade, and to serve as a place for trench materials and for troops to defend the working parties.

7. Construction of Simple Trench.—The direction of the trench is marked or traced upon the ground by engineer soldiers. This tracing is done before the working parties reach the ground, and care is taken to have no marks which will attract the attention of the besieged.

The working parties are detailed from the infantry; they are divided into reliefs, and marched to some convenient spot, not far from the place where the trenches are to be made, and then furnished with tools. On the arrival of the engineer officer reporting the tracing completed, the first relief, each man provided with a pick and shovel, moves forward to the ground where the trench is to be made, being led by the engineer officer. The relief is marched off by file, by fours, or in column, according to the features of the ground, with their muskets slung so as not to interfere with their movements. Upon reaching the ground, the men are extended along the line marking the direction of the trench, being directed in this movement by engineer soldiers, who show the men their places and their tasks.

The men are placed about five feet apart. Each man drives his pick into the ground on the left of his task, lays his shovel on the ground in front of him and just behind the line marking the direction of the trench, unslings his musket, takes off his waist-belt, places these on the ground behind him, and waits the order to begin work. It takes about five minutes to extend one hundred men.

In beginning the work, each man digs a hole about three feet in diameter, and four feet deep, obtaining cover in this way most quickly. The hole is then lengthened and widened to the limits of the given task. The portion, **A** (Fig. 1), shows the depth and width of the task of the first relief. The first relief having completed its task, returns to camp, leaving the tools upon the ground. The engineer soldiers who traced the line of trench return with the first relief. The engineer soldiers who came with the first relief remain in charge of the tools, and post the second relief when it arrives, showing the men their tasks. This relief completes the portion marked **B** in the figure.

The third relief widens the trench, as shown by **C**, and completes the lower step, revetting it with fascines.

During the execution of trench-work, strict silence must be observed. All words of command should be given in low tones, and the clashing of tools or arms carefully avoided. No lights, or smoking, should be allowed. Every precaution should be taken to prevent attracting the attention of the besieged in any way.

8. Flying Trench-work.—When the exposure of the working parties to the enemy's fire is considerable, the simple trench cannot be used. This is particularly the case when the men have to work within the range of canister. To shorten the time of exposure of the working parties to the enemy's fire, a more expeditious method of obtaining shelter must be used. One of the methods employed is that known as **flying trench-work** (Fig. 3), frequently called the **flying sap**. This method consists in placing a row of gabions in front of the line which marks the direction of the trench, and filling them as quickly as possible with earth. When the gabions are full, the remaining earth is thrown over and behind them, until a parapet of sufficient thickness is obtained. This method has to be employed to construct the second parallel, even when the first parallel has been constructed by simple trench-work.

9. Construction of Flying Trench-work.—The gabions to be used in this method should be carried beforehand to the first parallel, and placed in a single row along the reverse side of the trench.

The first relief, having been provided with their picks and shovels, is marched into the first parallel, and formed into a single rank near the row of gabions, each man standing opposite a pair of gabions. Each man fastens his shovel to the gabion on his right, and his pick to the one on his left. At the command, each man picks up the two gabions opposite to him; the relief is then marched to the spot where the line is marked upon the ground, showing the direction of the trench. The men are extended along this line, placing the gabions in front of, and close to the line, and in contact with each other. The extension of the men and the placing of the gabions are done under the direction of engineer soldiers, who are present to assist and to superintend the working parties.

The men take the tools out of the gabions, lay them on the ground behind the gabions, and then lie down themselves.

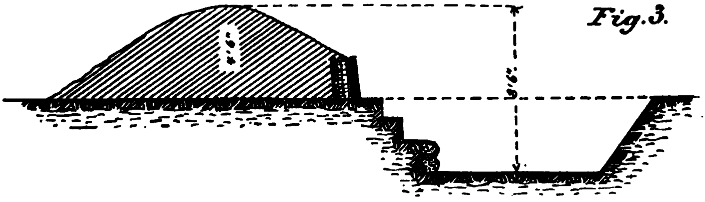


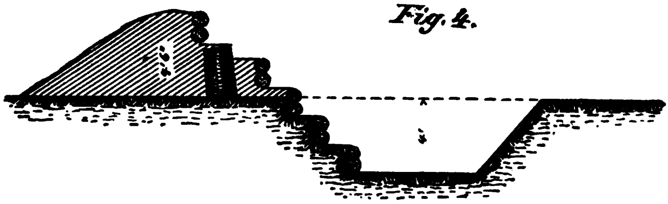
Fig. 3.

As soon as the gabions are all placed, the line showing the berme is marked, at a distance of about three feet back from the line along which the gabions were placed.

At the command, the first relief fill the gabions as quickly as possible. When about half-full of earth, the gabion is pushed at the top, so as to make it take an inclination of about $\frac{1}{4}$. When the gabion is full, the rest of the earth is thrown over the top, and close to the gabion, to make the screen, offered by it, a protection against the enemy's fire.

The dimensions of the profile (Fig. 3) of the second parallel are the same as those used in the first parallel, and the tasks are proportioned in a similar manner. The dimensions of the approaches and the tasks do not differ, when the flying trench-work is used, from those used in the simple trench. As it is frequently desirable to have the troops in the trenches move out of the trenches and over the parapet, in line, or with an unbroken front, it is usual to provide means for such a movement. This is done by arranging steps, not more than eighteen inches high and about eighteen inches wide, leading from the bottom of the trench to the top of the parapet, and extending the necessary distance. The length for a company front would be about twenty-five yards.

Fig. 4.



The profile of a parallel, constructed by flying trench-work, and arranged with **sortie steps**, is shown in Fig. 4. These steps are constructed after the third relief has finished its task, and are used in the simple trench as well as in the flying trench-work.

10. Saps.—The foregoing trenches have been constructed by working details from the infantry. These details, if left unmolested by the enemy's fire for an hour or two, will be able, in ordinary soil, to cover themselves and to continue their work without material loss, if the enemy's fire prove uncertain by reason of the obscurity of night, and ignorance of the exact position of the working parties.

But when the positions of the working parties are known to the besieged, and when they are close enough to the fortification to be within the range of small arms, the losses of the working parties will be so great that the methods of simple trench and flying trench-work will have to be abandoned, excepting under some very favorable circumstances.

The method which must be adopted for the extension of the trenches at this stage of the siege, is the one known as **sapping**. It is a method which requires specially trained workmen, who are known as **sappers**, and who belong to the engineer arm of service. The trenches made by them are known as **saps**, which receive distinguishing names according to the method used in their construction.

11. Single Sap.—The **single sap**, sometimes called **full sap**, is a trench where only one party of sappers is employed at its head. The parapet is revetted with gabions, which are placed in succession by the leading sapper. The sappers are protected in front by a **sap-roller**, or other bullet-proof mask.

A sap-roller is a hollow cylinder, seven feet and six inches long, made of two concentric gabions, the outer gabion having a diameter of four feet, and the inner one a diameter of two feet and six inches. The interval between the gabions, and sometimes the whole interior space, is stuffed tightly and compactly with small fascines and rods to render it bullet-proof.

12. Construction of Single Sap.—Single saps are divided into two general classes, the *deep*, and the *shallow* sap. The general principles of construction are the same for both kinds, the difference between the saps being principally in the depth of the trench. The shallow sap can be executed more rapidly, if the enemy's fire is not too severe, and is the one which will be described here.

To construct this sap a detachment, consisting of one non-commissioned officer and eight sappers, usually called a *brigade*, is detailed as a working party for eight hours. This detachment is divided into two sections of four men each, and the men in each section are numbered from 1 to 4.

The profile of the finished trench executed by the single sap is shown in Fig. 7, and is executed as follows:

No. 1, upon his knees, excavates a trench eighteen inches wide and eighteen inches deep, throwing the earth into the gabion next the sap roller, and leaving a berme eighteen inches wide. He then loosens as much earth as he can within the limits of his trench, working up as close as he can to the sap roller, so as to have earth enough ready to fill the second gabion. He calls for a gabion, which is brought by the leading member of the section not working, and is handed to No. 4, who passes it on by the hands of Nos. 3 and 2, into the hands of No. 1. Nos. 2 and 3 then push forward the sap-roller by

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Fig. 5

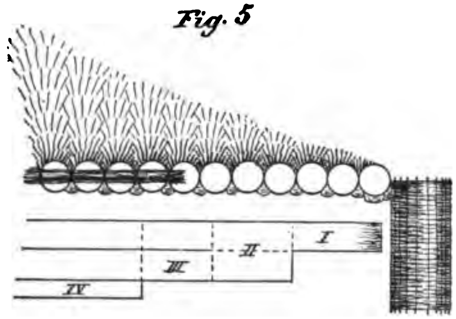
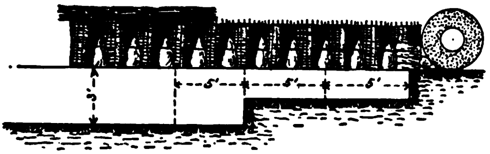


Fig. 6.



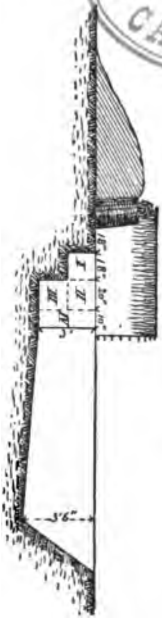


Fig. 7.

means of sap forks, and No. 1 inserts the gabion in the interval, as soon as the sap-roller is moved. He then fills this gabion as quickly as possible.

No. 2, kneeling, widens the trench made by No. 1, twenty inches, keeping it at the same depth of eighteen inches.

No. 3, who can work in a standing position, deepens the trench left by No. 2, eighteen inches.

No. 4 widens the trench left by No. 3, ten inches.

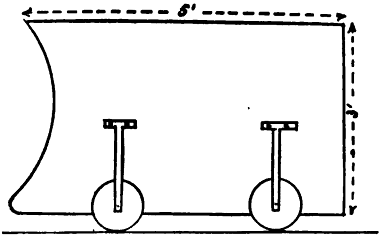
The interval between the sappers as they work is five feet. The plan of the sap, the longitudinal section, and the cross section, as shown in Figs. 5, 6 and 7, represent the details of the labors performed by this section. The section not working keep up the supply of gabions and other trench materials which may be required. The sappers lay their muskets on the ground within reach, ready to be taken up when needed.

No. 1, having placed and filled his gabion, gives up his place to No. 2; No. 3 becomes No. 2; and No. 1 becomes No. 3.

As soon as three gabions have been placed and filled, the section working is relieved by the one behind it, and the sapping is continued in a similar manner by the section which has been waiting. The widening and deepening of the sap to the full dimensions of the trench are executed by details from the infantry, which details are usually divided into two reliefs. The work of the first relief is to widen the trench five feet, and of the second to complete it.

The portion of the gabion in contact with the sap-roller, and the portions of the gabions where they touch, are weak places until they are covered by a sufficient thickness of earth to make them bullet-proof. To give protection to the sappers while working, it has been usual to fill the intervals with sand bags filled with earth, or to stand sap fagots (small fascines, three feet long) in these places. A better screen for this purpose is a sap shield, made of steel plate, about five feet long and three feet high. (Fig. 8.) This shield is mounted on wheels, and has the end curved so as to fit the sap roller when pushed close against it. As soon as the new gabion is placed, the shields are pushed forward until they touch the sap-roller and each other, in this way protecting the sappers from bullets passing through the first gabion and the junctions of those in rear.

Fig. 8.



As soon as the gabions are filled with earth, they are surmounted, or "**crowned**," as it is termed, by fascines, six feet long, placed lengthwise on the gabions. Sometimes three fascines are used, a layer of two, and on top of this layer a third; or there may be only one, as shown in the figure. No gabion is crowned until it is entirely filled with earth, and the work should be carried on so that not more than six gabions at a time remain uncrowned.

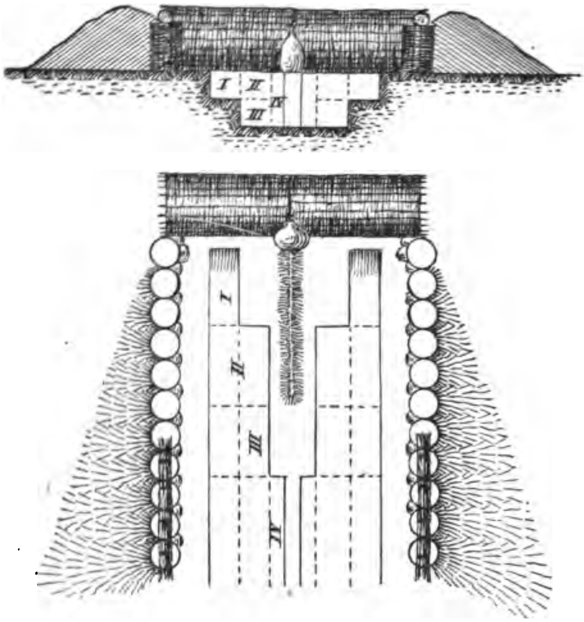
The sections of the brigade relieve each other, as has been stated. The one in waiting supplies all losses from casualties occurring in the one at work. No relief is sent to the brigade during its tour of eight hours, unless the number of sappers is reduced below four.

The advance of a sap is slow, being as little as three feet an hour in some cases, and rarely exceeding twelve feet an hour under the most favorable circumstances.

13. Double Sap.—The single sap may be used as long as there is no enfilade fire upon it, which will be the case when its prolongation passes outside of every point from which the enemy can direct their fire upon the trench.

As the approaches get very near the work, it will be seen that the length of a zigzag increases considerably in proportion to the corresponding advance obtained, if its prolongation is made to pass outside of the dangerous points, and that a very long trench has to be dug to obtain a short advance upon the work. Whenever the advance obtained is less than one third of the length of the trench dug, the results obtained do not compensate for the labor expended. Another method is then used, and the approach is made directly upon the point to be reached.

Fig. 9.



This direction of the sap exposes it to an enfilade, as well as to slant direct and slant reverse, fires. This reverse fire prevents the use of the single sap, and compels the employment of the method known as the **double sap.**

The trench made by using the double sap (Fig. 9) is executed by two, or more, single saps working abreast of each other. When two brigades of sappers are used, the trench will be no wider than the distance covered by the sap-rollers which are moved at the head of the sap to protect the sappers. When a wider trench than the one just mentioned is required, three brigades of sappers are used, the sappers being protected by four sap-rollers fastened together, or pushed along independently of each other.

The sappers at work on the double sap follow the same general rules as laid down for the single sap. In the case where two brigades are used, the working section of the right brigade excavates and throws the earth on the right hand, and that of the left brigade upon the left side. In the beginning of the work, Nos. 1 and 2 of these sections are separated from each other by a tongue of earth. They throw some of the earth which they excavate upon this tongue, and also some in and around the sand bags covering the junction of the sap-rollers, to add to the cover from the enemy's fire. This earth on the tongue is afterwards removed by Nos. 3 and 4, and the working parties which follow them.

Working parties from the infantry are employed to remove the rest of the tongue of earth left in the trench by the sappers, and to arrange the slopes of the sides of the trench. These slopes are made by cutting away the berme for six inches.

These parties also arrange the bottom of the trench so as to keep it drained from water falling into it.

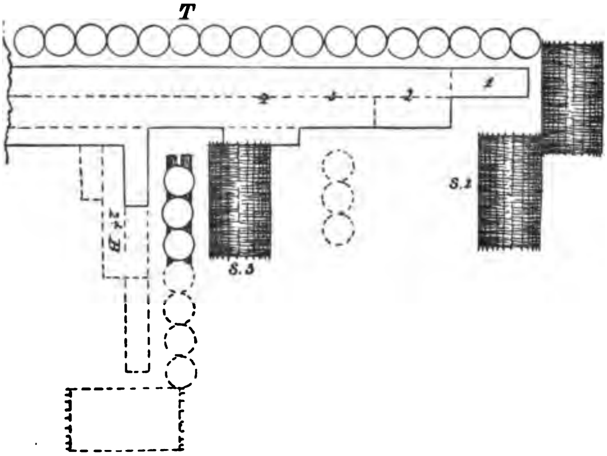
It is seen that the progress of the double sap is about at the same rate as that of the single sap.

14. Half-Double Sap.—Besides the single and the double saps, there is a third, known as the **half-double sap**, which is used under certain circumstances.

This sap differs from the single sap in there being more than one brigade of sappers used at the head of the sap, and from the double sap, in the positions of the brigades, which are not abreast of each other when working. Whilst the trench executed by the double sap has parapets upon both sides, that constructed by the half double sap has only one parapet. The trenches executed by the double and half-double saps are both exposed to enfilade and slant reverse fires, and have to be defiladed by traverses. When these traverses are joined to the parapet, they are called **attached** traverses; when they are not joined to it, they are known as **detached** traverses.

The half-double sap is begun as in the single sap, excepting instead of one sap roller, two are used (Fig. 10), one being in advance and overlapping the one behind it about one foot, to cover the leading sappers from the slant reverse fire. If the reverse fire becomes quite oblique, a temporary parapet of sand bags filled with earth may be used, being removed later when the trench is widened.

Fig. 10.



Numbers 1, 2, and 3 execute the sap as described in Art. 12. As soon as No. 4 has reached the gabion next to one at T

(Fig. 10), opposite to which a traverse is to be constructed, he has one or two sap rollers brought forward from the rear, to be used in the construction of the traverse. He then places two fascines, six feet long, on the reverse side of the trench and in a line with the direction of the traverse. Since this traverse is to be an attached one, No. 4 does not continue to widen the trench made by No. 3, but places three gabions on the fascines just laid, and excavates behind them a trench eighteen inches wide, eighteen inches deep, and five feet long, throwing the earth into these gabions and leaving a berme of eighteen inches wide. This trench forms a protection for the second brigade, whose duty is to construct the traverse and drive the sap around it. The sap is completed around the traverse, and the trench between it and the parapet, made by the saps of 1, 2, and 3, is then closed.

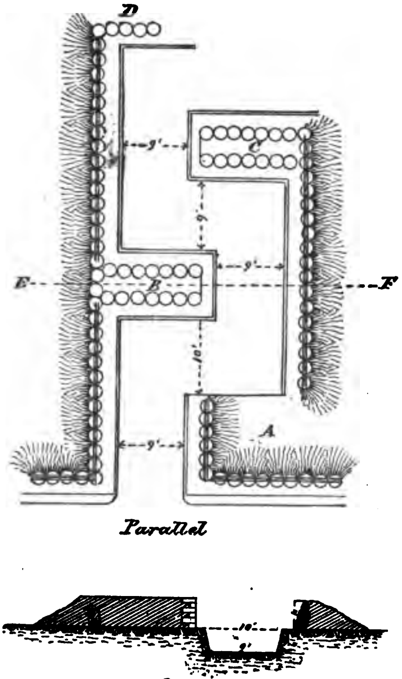
If the reverse fire between sap rollers 2 and 3 becomes troublesome, a temporary traverse, made of three gabions filled with sand bags, can be used, as shown in the figure by the dotted circles, or a sap roller can be employed.

The characteristic feature of the half-double sap is the use of the temporary protections from reverse fire upon the reverse side of the trench, which have to be removed when the trench is widened.

15. Defilade of an Approach.—The parallels and those zigzags whose prolongations pass outside of the fortification are defiladed by the parapet of the trench. But when the approach is directly toward the fortification, the trench, as the sap advances, soon becomes exposed to an enfilade fire coming over the top of the sap roller. It is necessary to defilade the trench from this fire, and this is done by means of traverses in the trench. These traverses are constructed by the sappers, and their position when used in the double sap, is shown in Fig. 11.

The traverses, **B**, **C**, etc., are placed at intervals, sufficiently near each other to defilade that portion of the trench in their rear; and usually they are placed on alternate sides of the trench. They should not be nearer than nine feet to each other, if artillery is to be drawn through the sap. In the figure, the distance between the traverses **B** and **C**, measured between the rows of gabions, is twelve feet. Leaving a berme of one foot for each traverse, and allowing one foot for the slope of the sides, this gives a width of nine feet at the bottom of the trench. The thickness of these traverses is taken in the figure to be equal to three gabions, and the height to be four feet above the natural surface of the ground. The intervals, as well as the height and the thicknesses, of the traverses, vary with the command of the besieged work, and with the penetration of the projectile. It is recommended to crown the gabions of the traverses with sand bags, in preference to using fascines.

Fig. 11.

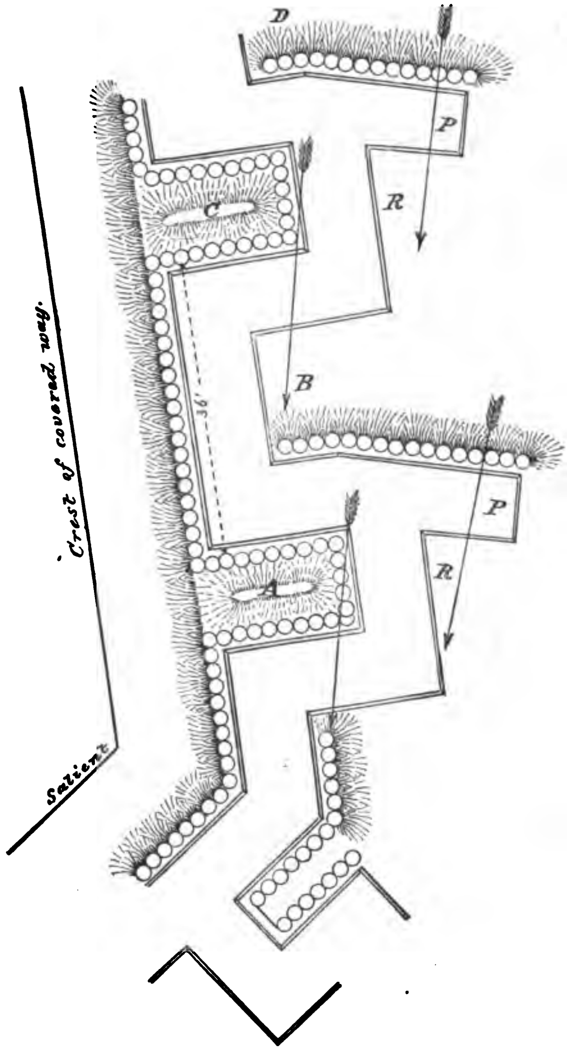


Section on E.F.

When the crest of the glacis is reached, the trench is extended along the glacis and parallel to the crest. The method used is the half double sap, and the traverses used in this case to protect the trench from the enfilade fire are shown in Fig. 12.

The traverses **A** and **C** are **attached** traverses; those at **B** and **D** are **detached** ones (Fig. 12.)

Fig. 12.



It will be observed that the trenches in rear of the detached traverses change their direction and are prolonged some distance beyond the reverse sides R, R, of the trench parallel to the covered way. These prolongations, P, P, are made perpendicular to the direction of the slant reverse fire to which the main trench is exposed, and are extended far enough to cover it from this fire by the parapet or traverse formed from the excavation.

When very near the work the trenches cannot always be defiladed by traverses alone, in consequence of the command of the fortification. In this case, the engineers make use of **blindages** in connection with the traverses, or blindages alone. A sap is said to be blinded whenever it is provided with a shot-proof shelter overhead. This shelter is usually provided by using blindage frames, made of either round or square timbers, similar to the gallery frames used in mining, placing these in position, covering the tops with planks laid longitudinally, then with fascines laid transversely upon the planks, and then with from two to three feet of earth on top of the fascines.

16. Descent into and Passage of the Ditch.—If the artillery fire of the defense has been kept under, the besiegers will succeed in reaching the glacis by the use of the single and double saps. By use of the half-double sap, they will be able to place breaching batteries upon the glacis, and with these to break down the revetments which prevent their assaulting the fortification.

If the counterscarp is revetted, it may be mined and blown down. After this has been done, a descent may be made by running a sap down the breach.

It ordinarily saves time to let the wall stand, and to make the descent by a gallery. The galleries are constructed like those described under the head of **mining operations.**

When the ditch is dry, the bottom of the gallery should be at least three feet below the bottom of the ditch at the point where it breaks through the counterscarp wall. The passage across the ditch is effected by a trench constructed by one of the saps already described. If the ditch is a wet one, the gallery should come out about a foot above the surface of the water. The ditch is then crossed by means of a bridge, or by a causeway. If there is a current, a bridge would be used; if no current, either the bridge or the causeway may be used, circumstances deciding which can be constructed in the least time and with the least difficulty.

The passage of a wet ditch is a very difficult operation, and an exceedingly dangerous one, if the enemy are on the alert and make a vigorous resistance. A floating mask will be necessary for the protection of the men constructing the head of a bridge. This mask may be a shield made of planks, lined with iron or steel plates, and placed upon a raft which can be moved forward or drawn back, similar to the method of a sap roller.

The time occupied in crossing the ditch, if dry, depends upon the rate at which the sap is driven. If wet, it depends upon the fire of the besieged, and upon the rapidity with which the causeway or the bridge can be built. In either case, if a bridge or a causeway, materials must be brought forward to build these structures and to construct on them a parapet.

The besiegers, having crossed the ditch, make arrangements to enter the work through the breach, if one exists. There are two methods used; one is to run approaches up the breach by the saps; and the other is to carry the breach by assault. The former method differs in no way from the saps already described. The latter is usually followed by what is known as the **lodgment.** A lodgment is a trench on the summit of a breach, executed by the method of flying trench-work, by a working party which follows close to the assaulting column. From the lodgment, saps are driven along the parapet, or on the terre-plein of the work, according to circumstances.

CHAPTER II.

SIEGE BATTERIES.

17. Battery.—The term, **battery,** is used to designate a place prepared for the reception of cannon or mortars, from which the fire of the pieces can be effectively delivered, and in which the guns and the men serving them can be covered wholly or in part from the fire of an enemy.

This term, **battery,** is also used to designate a collection of guns placed under the command of a single person, and is also applied to the company of soldiers in charge of the pieces. In siege operations, the place prepared for the guns is the one which is meant.

Batteries are divided, according to the position of their terre-pleins, into **elevated, half-sunken**, and **sunken batteries**; according to the kind of artillery they are to contain, into **gun, howitzer,** and **mortar batteries**; according to the object to be attained, into **enfilading, counter,** and **breaching batteries,** etc.

Batteries having the platforms for the guns resting upon or above the natural surface of the ground are classed as elevated batteries. When the site of the platform is below the natural surface, they are known as half-sunken, or sunken batteries, according to the depth of the platform below the surface. When the gun is placed so that the sole of the embrasure is entirely above the natural surface of the ground, the battery is a half-sunken one. When the sole coincides with, intersects, or lies below the natural surface, the battery is a sunken one. The distance of the platform below the throat of the embrasure is about three feet, for the ordinary siege gun.

The terms, howitzer batteries, mortar batteries, etc., depend upon the kind of artillery used, and require no explanation.

Batteries are constructed with certain objects in view. Those having for their object to bring an enfilade fire upon a terre-plein, or to rake a line by the fire from the battery, are termed enfilading batteries. If the object is to silence the fire of the enemy's guns, by firing directly at the embrasures, the batteries are known as counter batteries. When the object is to break down a scarp wall, or to destroy a parapet, the batteries are called breaching batteries.

18. Construction of a Battery.—The general principles governing the construction of field works and of trenches apply to the construction of batteries. The plan of one-half of an elevated battery, and a section through one of the embrasures, are shown in Fig. 13.

The parapet of an elevated battery is made of the earth obtained from the ditch in front.

The tracing of the battery is made in a similar way to that for other field works, and by sappers, under the direction of an officer of engineers. The principal lines traced upon the ground are the sub-crest, the foot of the exterior slope, the foot of the interior slope, the lines of the ditch, and the directrix of one of the embrasures. This latter line, **A B**, must be traced, if possible, during the day time, when the line of fire can be accurately determined; the other lines may be, and usually are, marked after dusk.

The working parties are placed and the work begun as soon as the tracing is completed.

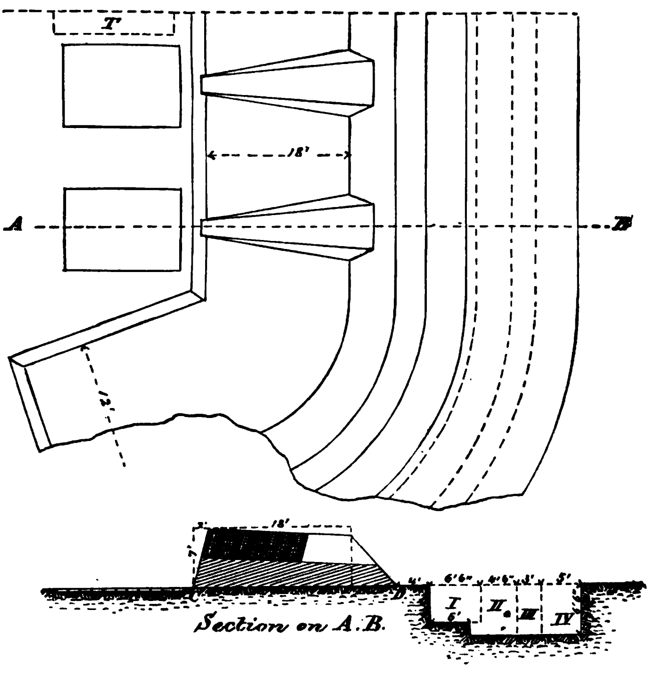
In the construction of a battery, like that shown by

Fig. 13, there are usually four reliefs, with tasks assigned them.

The task of the first relief is to dig along the line of the ditch a trench which shall be six and one-half feet wide, and five feet deep. The earth from this trench is thrown as far as the workmen can throw it in the direction of the battery.

The task given to the second relief is to widen this trench four and one-half feet, and to deepen it to a depth of six and one-half feet, leaving a step five feet wide, as shown in the figure.

Fig. 13.



The task of the third relief is to widen the trench, left by the second relief, a distance of three feet.

The task of the fourth relief is to widen the ditch a distance of five feet.

The different tasks are indicated in the section shown in Fig. 13.

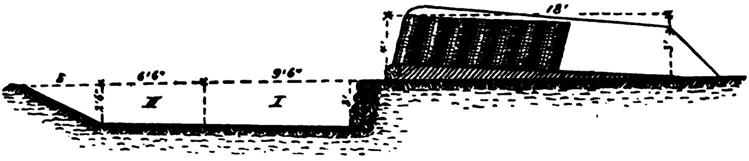
The earth thrown out by the first relief is spread out, and used to form the inner part of the parapet. The earth thrown out by the second relief is used to form the body of the parapet. The tasks of these two reliefs, if the soil is good, can be completed during the night, and before daybreak.

The earth thrown out by the third relief will require to be handled twice; first, from the excavation to the berme, and second, from the berme to the parapet, where it has to be spread and rammed. This second part cannot be done during the day, although by the cover afforded by the ditch, the first part may be executed. The digging is therefore prosecuted during the day, the earth being thrown upon the berme. As soon as it is dark, workmen are placed upon the berme and parapet to handle this earth and spread it out on the parapet.

The completion of the fourth task gives all the earth necessary to form the parapet.

19. Sunken Batteries.—In batteries of this class, the earth for the parapet is obtained from the trench in rear of the work. A section (through an embrasure) of a sunken battery is represented in Fig. 14.

Fig. 14.



The profile of the parapet is practically the same as that used for the elevated battery. The terre-plein is taken three feet below the natural surface of the ground, with a slope toward the parapet, as shown in the figure. In soil easy to excavate the parapet may be made by two reliefs, the tasks being indicated upon the section.

When the battery is a half-sunken one, the earth is obtained both from the trench in rear and from the ditch in front.

It is seen that the time required to construct a sunken battery is much less than that for an elevated one.

20. Details of Batteries.—The earth being obtained for the parapet, it is necessary to fix upon the height and the thickness to give it, and to arrange the interior to receive the armament and to shelter the defense.

The rules used in field fortifications to determine the height and thickness of a parapet are applicable to batteries.

The least height is that one which screens the men serving the guns, when standing near to and in rear of the gun platforms.

The least thickness is that which gives protection to the men sheltered by the parapet. This thickness depends principally upon the kind of earth used in the construction of the battery, and upon the penetration of the enemy's projectiles.

A thickness of eighteen feet of ordinary earth is considered sufficient, when the enemy possesses only smooth-bored guns of ordinary calibres. If the enemy has sea-coast artillery, or large rifled cannon, the thickness must be increased.

The inclination of the superior slope will depend largely upon the position of the battery, whether near to or distant from the place attacked, and whether on the same or on a different level with the object to be reached by its fire.

This slope may be outward, as in ordinary field works, or horizontal, or even inclined inward.

The interior slope is made as steep as possible, to allow the guns being run in close to the parapet.

The exterior slope has an inclination given it somewhat less than the natural slope, to allow for the wear produced by the enemy's projectiles striking it.

Embrasures are used and are constructed as in field works. The splay is made much less, as there is a more limited field of fire. The throat is made as small as possible, with vertical sides, or nearly so, and a little larger for howitzers than for guns.

The cheeks of the embrasures are protected from the blast of the gun by revetments for a distance of about half that of the thickness of the parapet. These revetments are of sand-bags, gabions, or other suitable materials. The revetments near the throat are usually made of gabions filled with sand-bags full of earth. The gabions are held firmly in place by stout pickets driven in them and into the earth on which they are placed, and are protected from fire and the blast of the gun by green raw-hides stretched over them.

If the battery is to be armed with heavier guns than are ordinarily found in siege trains, it is advised to change the form of the embrasure in plan. This change is made by widening the embrasure from the throat to a point about midway between the throat and exterior opening of the embrasure, making the plan of the sole an oval in shape. From the middle point to the exterior opening, the embrasure has the usual form. Embrasures of this kind are known as **oval embrasures.**

Embrasures should be provided with means to intercept the bullets of the enemy's sharp-shooters, fragments of shells, etc. The usual expedients are shutters of iron or wood, rope mantelets, and other devices which close the throat of the embrasure. In addition, the external openings should be concealed from the enemy's view, or they will offer good marks for the enemy's gunners to aim at.

Traverses are necessary to shelter the gunners when serving their pieces. They are of the kind known as "splinter-proof" traverses, and are joined to the parapet, or separated from it by a narrow passage. There may be one between each pair of guns, or there may be one for each gun.

Magazines for ammunition must be constructed for each battery. They are usually placed in rear of the battery, and near enough to be convenient to the guns, and also to have partial protection from the parapet of the battery. These magazines are constructed in a similar manner to that described for magazines in field works. Their sizes will depend upon the amount of ammunition they are to hold, and the space necessary for the men who are to prepare the ammunition for immediate use.

The platforms are laid and the guns mounted as soon as the necessary shelter is afforded by the parapet.

If the battery is liable to be exposed to an oblique fire from the enemy's guns, it will be necessary to defilade the interior of the battery by running back wings, as shown in the figure. These wings are simple epaulements of the same height as the parapet, and about two-thirds as thick. They usually make an angle of from one hundred to one hundred and thirty degrees with the interior crest of the battery, and are prolonged back until the defilade is complete. The earth for their construction is obtained from a ditch on the outside of the epaulement.

21. Screens for Batteries.—A battery cannot be constructed and armed between dusk and daylight of a single night, unless under very peculiar circumstances, but requires a second night's work to finish it. It becomes necessary to choose positions where the work shall be hidden from the view of the enemy, and where the enemy shall not know positively the location of the battery.

Many natural screens, like hedges, fences, or other obstructions, may be utilized for this purpose. But where they do not exist, artificial screens should be used.

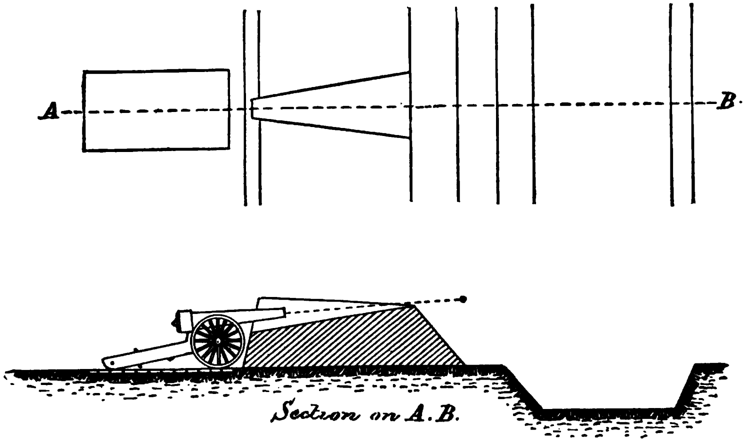
Batteries constructed in rear of a trench can be easily hidden from view by the parapet of the latter, without interfering with the fire of the guns.

This screen should not be less than twenty yards from the interior crest of the battery, and should have a direction parallel to it.

These screens are useful to hide the embrasures of the guns, which offer good marks for the enemy's fire where they can be seen.

The embrasures may be hidden frequently by countersloping the superior slope, as shown in Fig. 15.

Fig. 15.



It is to be remembered that a prompt construction of a battery in the presence of an enemy and within his range of fire, requires that it be constructed undiscovered by the enemy; and it is advisable to take all precautions which will make it a difficult thing for the enemy to distinguish their exact positions even when the batteries have opened their fire.

In addition, it is well to remember that the construction of a battery requires a great amount of labor, and that the less the amount required for a battery, the better it will be for the soldiers who have the labor to perform. It follows, therefore, that an elevated battery should never be employed, if a sunken one would suffice.

Sometimes it becomes imperative to use elevated batteries, as in the case of rocky soils, or where water is found close to the surface of the ground, etc. Mere obstructions to aiming the guns are not necessarily obstacles to firing, because of the large angles of elevation ordinarily used at the present time. Arrangements can easily be made to aim the piece correctly, although the object aimed at cannot be seen by the gunner when standing by the piece.

Batteries are usually constructed so as to have their interior crests perpendicular to their lines of fire, as this requires the least amount of earth for the parapet. Sometimes it may be necessary to vary this method, in consequence of the site on which the battery is to be placed and to use oblique embrasures. The method employed when the directrix of the embrasure makes an angle with the interior crest greater than ten degrees is by "**indenting**" the interior crest. This method requires a great amount of labor, and is used only when it becomes absolutely necessary.

22. Location of Batteries.—The position to be given to a battery depends primarily upon the objects to be attained by its fire. These objects to be attained are as follows: to counterbatter some part of a work; to enfilade some portion of it; to break down an obstacle, or to breach a parapet; and to throw projectiles over intervening obstacles, letting them drop upon parts of the interior of the defences. To counterbatter a work is to silence the guns in it, by a direct fire upon them. Batteries having this object in view are known, as before stated, as counter-batteries. The position of batteries of this class should be such as to allow a direct fire from them upon the parts of the work to be silenced. It is evident that the best direction to give the interior crest of a counter-battery is one which is perpendicular to the fire to be silenced; and to be effective in its results, the total fire of the battery or batteries arranged for this purpose should be greater than the fire which is to be silenced. This latter condition requires either a greater number of guns of the same calibre as those to be silenced, or a number of guns of greater calibre, in order to obtain the necessary amount of fire and weight of projectiles.

To enfilade a portion of the work is to sweep the crest or terre-plein with a fire parallel to the crest or face of the part selected. The best direction to give the interior crest of an enfilading battery is one which is perpendicular, or nearly so, to the prolongation of the line to be enfiladed; and the position of such a battery is in the angle made by the prolongation of the diagonals of the terre-plein to be swept. The best place for the batteries in this angle will be along the prolongation of the line to be enfiladed, and on that side of the prolongation which will admit of a slant and reverse fire upon the face enfiladed.

Breaching batteries should have their lines of fire direct, and be near enough to the part to be breached to employ the full penetrative effect of the projectiles. Revetments of permanent works exposed to an enemy's fire are usually masked by a glacis, or by an intermediate work. In cases of this kind, a breach, *practicable* to be used by an assaulting force, can only be made by guns placed upon the glacis, or upon the terre-pleins of the intermediate works which mask the wall to be breached. If the revetments are not masked, but are exposed to the view of the besiegers, the breaching batteries may occupy any position within effective range of the guns, from which the fire of the batteries can be directed upon the parts to be breached. The direction of the crests of these batteries should be as nearly as possible parallel to the revetments to be battered down.

Batteries to be used in throwing projectiles over intervening obstacles and for the purpose of inflicting injuries upon the defences, may occupy any position which is convenient for their service.

Mortar batteries belong to this class, being especially serviceable in throwing shells into the interior of those works which could not be enfiladed.

Batteries armed with heavy rifled guns are also used for a similar purpose. The guns are fired at long ranges, and with high elevations, and are so directed as to have the projectile graze the parapet in the descending portion of its trajectory. These guns are sometimes used to reach a scarp which has been screened by an earthen mask, and the effect of the projectile is to damage and finally breach the revetment.

The distances of all these batteries from the work to be attacked must depend upon the range of the pieces employed, and upon the nature of the ground.

23. Observatories.—Arrangements should be made so that the flight and the effect of the projectiles can be observed. Especially must this be attended to in the distant batteries, to avoid the waste of ammunition. Secure places of observation, made safe by sand-bags filled with earth, have been used, and in these observers placed, and provided with strong field glasses to watch the projectiles and notice their effect.

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CHAPTER III.

ATTACK OF A FORTIFIED PLACE.

24. Regular Approaches.—A position which is strongly fortified and well defended cannot be taken by an open assault. If the garrison is well supplied with munitions of war and the necessary supplies of food, it will take a long time to reduce the place by either a bombardment or a blockade. Under these circumstances, the "systematic attack" or "regular siege" becomes necessary, and the advance upon the place is made by the method of **regular approaches** (Art. 4).

A regular siege includes all the operations by which the attacking forces approach the work under cover, and remove the obstacles in the way of an open assault; and finally in taking the place by storm if it is not surrendered.

25. Preliminary Operations.—Before any movement against the works is made, all information should be obtained which would give to the besiegers a fair knowledge of the strength and kind of fortifications to be attacked, of the numbers and condition of the garrison, the character of the officer who has the command, and of the probabilities of an attempt being made to reinforce the garrison, or to raise the siege.

This knowledge is essential in determining the numbers and composition of the troops to be employed in the attack, and in fixing the strength and numbers of the engineer and siege trains.

It is possible that a part of this information may already be in the hands of the authorities ordering the siege, but even this portion should be verified by careful reconnoissances, and by reports obtained from deserters and spies.

26. Strength of the Besieging Forces.—The besieging forces must be strong enough to invest the place, and to keep the investment from being broken by attacks from within, or from without. Also, they should be strong enough to furnish the working parties who are to execute the siege works, and a sufficient number of men to defend the working parties and the works after they are constructed.

Rules have been given for the numbers to be employed, based upon the kind of works to be attacked, and upon the strength of the garrison; but as no two cases are hardly ever alike, the relation which should exist between the numbers of the besiegers and the besieged cannot be accurately determined.

It seems safe to say that a complete investment entirely surrounding a work, would require at least a number double that of the garrison, when there is no danger to be expected of an attempt being made to relieve the garrison from the outside; and that double this number would be necessary to execute the siege works and defend them. In other words, a successful termination of a siege in the shortest time would fix upon six to one as the proportion of besiegers to besieged. Thus, a garrison numbering 5,000 men, in a good defensive work of a permanent class, would require that the besiegers should number about 30,000.

Sieges have oftentimes been undertaken with numbers much less than this proportion just given, and have been brought to a successful termination.

Strasburg was besieged in 1870 by the Germans. The garrison numbered 20,000, and the besiegers 60,000, or only three times as many. The investment was made on the 10th of August, 1870, and the surrender of the city took place on the 28th of September, a period of forty-nine days.

Belfort, with a garrison of 16,000, was besieged during the same war by a force of 36,000. This siege made slow progress, and was terminated by other events not connected with the siege operations.

The kind of defense made by a garrison, the nature of the ground, the greater or less amount of development of the siege works, and the rapidity with which the siege must be pushed forward, all modify materially the proportions to be used.

27. Composition of the Besieging Forces.—All four arms of the service will be necessary for an active prosecution of siege operations. The proportions will vary somewhat from those used for an army in the field, being much greater for the artillery and engineers, and less for the cavalry.

It is thought that, taking the infantry as the unit, the engineers should number at least one-twentieth. The number of engineer officers should also be largely increased.

The engineer companies are provided with their usual equipment trains, which are supplied with all the sapping and mining tools that may be required. In addition to these special equipments, there should be a supply of intrenching tools for the use of the working parties. These tools are shovels, picks, hatchets or bill-hooks, axes, sand-bags, etc. The supply should be sufficient to provide tools for a force three times as great as the largest working party that will be employed. That is, if the largest working party be estimated at 4,000 men, there should be tools enough to supply 12,000.

The proportions of the tools vary considerably, but under ordinary circumstances, where there is a good deal of brushwood to be used, the following estimate has been made: For 16 shovels, there would be 8 picks, 2 hatchets or bill-hooks, and 1 axe. For every 1,000 shovels, there are 4 sets of carpenter's tools, 3 sets of blacksmith's tools, and from 10,000 to 12,000 sand-bags.

These are approximate, being, like all other estimates, subject to variations according to the conditions surrounding the place to be attacked.

The strength of the artillery is largely increased, but no estimate can be fixed in advance.

The proportions of light to heavy guns, the number of guns, and their calibres, depend upon the strength of the garrison and of the defences. The great desideratum is to be able to bring a heavier fire upon the besieged than they can return. The ease with which temporary railroads can be constructed and operated in these times, will cause heavier guns to be used in the attacks of the future than was the custom in the past. As to numbers of guns, the Germans had 373 pieces at the siege of Strasburg, but used only 243 of them. At Sebastopol the allies brought into use at their last bombardment 698 guns.

Ammunition must be provided in quantities not to allow a cessation of fire, by a failure of the supply, after the batteries have opened. It is usual to allow in the beginning 500 rounds for each gun.

28. Investment.—The investment will be more efficacious if it partakes of the nature of a surprise. It should therefore be made as quickly as possible when begun. The effect of a quick investment will be to prevent reinforcements and supplies reaching the garrison, which may have been hurried forward by the enemy, upon hearing or learning of the threatened attack.

A rapid movement of this kind may require that the investing forces should move in separate columns, so that all the avenues of approach to the place may be simultaneously seized. A movement of this kind in an enemy's country, when the enemy is active, becomes an exceedingly delicate one, and requires an accurate knowledge of the country, a knowledge of the positions of the enemy's forces, and the use of mobile and good troops, to make it successful.

It is evident that the number of troops employed in this operation should be greater than the garrison, or the investing force should be at least twice that of the besieged.

The main body follows as quickly as possible, taking up a position convenient to the front of attack, and supports the investing force.

The investment is not always quickly done, but sometimes is made gradually. In the case of an enemy falling back, and seeking shelter under the fortifications, it is plain that the plan of divided columns would be a risky one. Under these circumstances, the attacking forces are kept together and are advanced upon the side of the fortification where the attack is to be made. As soon as a position as near the work as it is prudent to occupy is taken by the advanced division or corps, the divisions in rear move forward and extend their lines upon the flanks, until the place is invested. Of course the nearer this line of investment is to the place the shorter it will be, and the less will be the work required in the siege operations which are to follow.

As soon as the investing force is in position, outposts are thrown forward, who, with their sentinels, guard and watch all the ground in their front. It is usual to push this line nearer to the works at night than during the day. This line is designated as the **daily cordon,** or **nightly cordon,** according to the position occupied.

The outposts provide themselves with cover, employing both natural and artificial means for this purpose, so that they may be able to repulse any sorties that the garrison may make. Where serious fighting is probable, positions in rear of the outposts should be prepared, into which the outposts can rally, and with their reserves, obstinately contest the sorties until this defensive line can be reinforced by the main body.

If it is too dangerous to attempt the complete investment on all sides, because of the weakness of the force sent forward, it is recommended to choose a favorable position which can be held, and which controls the main approaches to the place, and then, by means of the cavalry, obstruct and render unsafe all the other approaches until the main body arrives.

29. Lines of Countervallation and of Circumvallation.—The main body of the besieging forces having arrived upon the ground, attention is at once paid to locating the camps of the troops, parks, and trains, and to making the necessary preparations for beginning the active and systematic operations of the siege.

If there is danger of the garrison making sorties in force, it may be necessary to protect the general position of the besieging forces by a line of defensive works. Works of this kind are termed **lines of countervallation.** If there is danger of a relieving force attempting to raise the siege, a position should be chosen in which the besiegers may resist this movement. If a line of works be used for this purpose, it is usually known as a **line of circumvallation.** Lines of circumvallation were formerly used to a greater extent than they will ever be again, in consequence of the greater mobility of modern armies, and for the reason that a besieging force would find it better to move from its position and meet the relieving army in some other place, than to wait to be attacked in a position occupied near the besieged place.

30. Reconnoissances. — Simultaneously with the investment, reconnoissances are made for the purpose of verifying the information already in the possession of the besieging forces, of correcting errors existing in the plans and descriptions of the fortifications, and of determining the natural features of the ground over which the approaches must be made. Instrumental surveys should accompany these reconnoissances, as far as they can be pushed, to determine accurately the distances, the true directions of the lines of the defence, and the location of obstacles to be encountered. Particular attention is paid to obtaining the directions of the principal faces of the works and the prolongations of those lines which are useful in determining the positions of the siege batteries.

31. Choice of Point of Attack.—The part of the work selected for attack is known as the **point of attack.** There are several considerations which govern the selection of this point. Some of them are as follows:

1. The nature of the ground, or side of the work upon which it is easiest to construct the approaches;
2. The strength of the works upon this side;
3. The value of the point of attack when in the possession of the besiegers in determining the final surrender of the main work;
4. The selection of that side which affords the best position for the establishment of the depots of supplies, endangers least the lines of communication, is most suitable in case of attempts being made to raise the siege, and exercises a favorable influence upon the consequences which follow the capture of the place.

As to the nature of the ground, the difficulties met in constructing approaches where rock or water is near the surface, are easily appreciated. The slope of the ground has also to be considered, as the parapets have to be constructed of greater dimensions when the slopes are not favorable, and the problems of defilade are more difficult to solve.

As to the strength of the works, they may sometimes, from the location of their sites, like those bordering marshes, near unfordable streams, or upon precipitous heights, be regarded as practically inpregnable. Again, others may be considered as unassailable, from their being commanded by works in their rear, or by being strengthened by fires from neighboring works.

As to the value of the point of attack, it is evidently a waste of time to attack a point whose fall results only in the possession of that part. The part selected should be one which being obtained gives possession of the rest, or at least exposes the main work to an attack by an open assault.

As to the last condition, it is plain that the labors of the siege will be much less if the parks and depots of supplies are near the side to be attacked. It is also evident that the lines of communication must not be interrupted, and no danger must be apprehended from a relieving force. If the side selected can, when taken, add to the consequences arising from a successful siege, this consideration is to be fully weighed in selecting the point of attack.

32. Plan of Attack.—After considering all these things, a plan is drawn up by the senior engineer officer on duty with the besieging forces, showing the methods to be employed, the point selected, and the possible duration of the siege. This plan is submitted to the general in command of the besieging forces, and is approved or rejected by him.

When approved, arrangements are immediately begun to carry out the contemplated plans. As soon as the point of attack is selected, attention is paid to arranging shelters for the troops to be employed in the siege operations, and for the supplies. The great object in view will be to have the men and supplies upon the side to be attacked, and as near as possible consistent with shelter. The nearer the men are to the place where they are to work, the less fatigue will they suffer by their marches to and from the trenches.

33. Parks.—The engineer and artillery trains should be assembled at points out of range of the besiegers' guns, and at the same time be placed in positions convenient for supplying the working parties employed, and for supplying guns and ammunition to the batteries, as fast as they are built. While these parks are being established, attacks are made upon the garrison. The outposts push up nearer to the place, strengthening themselves and holding their advanced positions by means of hasty entrenchments and rifle pits. Field artillery can be of service at this epoch, by throwing shot and shell into the outworks, and by this fire hindering the besiegers in making their preparations which are usually necessary to complete the defences exterior to the works.

34. Trench Materials.—Simultaneously with the establishment of the parks, details are made to procure the trench materials necessary to be employed in the construction of the approaches.

It is recommended to have sheds erected, and to bring the brushwood and timber to these places, where, under the supervision of sappers, the gabions, fascines, sap-rollers, etc., can be made. When completed, these trench materials can be sent to the depots for distribution.

As fast as the forward progress will admit, depots for the trench materials are established nearer to the works, and these depots are arranged to contain sufficient materials to last for at least twenty-four hours. It will be from these advanced depots that the trench materials are obtained for the smaller depots in the trenches.

35. Preliminary Batteries.—In connection with the forward movement of the outposts and the attacks of the light batteries, it is usual to establish batteries for heavy guns, which, when armed, are used to test the besiegers by a preliminary bombardment.

These batteries are constructed on different sides of the place to be attacked, and are so situated as to bring the required fire upon the place, but at the same time to be hidden from the enemy's view during the process of their construction.

From their distances from the point of attack, it becomes necessary to use guns of long range, and to fire them at high angles of elevation.

There is considerable doubt in the minds of engineers as to whether the effect of the fire of the preliminary bombardment pays for the amount of ammunition used, especially when it is necessary to resort to the systematic attack to take the place.

36. Periods of Attack.—All that precedes has been for the purpose of getting ready to lay out and construct the **first parallel.** For convenience of description, it is usual to divide the attack into **three periods.** All operations preceding the laying out of the first parallel are classed in the **first** period; all from the laying out of the first parallel until the completion of what is technically known as the third parallel belong to the **second** period; all from the completion of the third parallel until the end of the siege are embraced in the **third** period.

37. First Parallel.—The object of this parallel is to provide a sheltered position, facing the side of the work to be attacked, for an extended front of infantry; this infantry being used as supports to the batteries employed to reduce the fire of the fortifications, and to protect working parties engaged in their labors.

In addition to this use, the first parallel forms a secure base of operations for further advance upon the point of attack.

It is desirable to establish the first parallel near the work, so as to lessen the labors of the siege as much as possible. In former times, when the cannon used were smooth-bored, and the range of the musket was about 200 yards, it was possible to establish this parallel at a distance of about 600 yards from the salients of the outworks belonging to the front to be attacked.

The usual method of constructing this parallel was to conceal from the garrison all knowledge of the night chosen to begin the work, and to deceive them even as to the side to be selected. As soon as it was dark, engineers traced the lines of the trenches, and the troops, with intrenching tools, were marched to the spot. If the working parties were not interrupted, the parallel was practically constructed by morning, and could be used as a shelter for the troops guarding the working parties employed upon the batteries during the second night.

If the working parties were discovered, very little loss would be inflicted by the fire from the weapons then used, and sorties could be repelled by the troops which acted as supports to the working parties.

The increased range and efficiency of the small arms and the cannon of the present time prevent the method formerly used, of first constructing the first parallel, and then the batteries by which the fire of the front of attack was silenced, from now being employed. For, supposing that from want of vigilance it was possible to finish the first parallel within 600 yards of the point of attack, the difficult task of constructing the batteries would still have to be executed; and, if located, as formerly, in front of the parallel, the batteries would have to be built within close range of a heavy artillery fire from guns already in position.

Instead, therefore, of placing the batteries, in the beginning, so close to the front of attack as 600 yards, it is considered better to establish a line of batteries within effective range, and with sufficient weight of metal to silence, or keep down, the artillery fire of the front of attack. Then, under the protection of this fire, to move forward and begin the first parallel. This line of batteries is known as the **first artillery position.**

38. First Artillery Position.—The first artillery position, as it is seen, consists of a number of batteries, armed with heavy artillery, within effective range of the work to be attacked, and so situated that their fire can keep down the fire of the enemy's guns bearing upon the ground over which the approaches must be made.

The batteries are separated from each other, and widely distributed, so that a strong converging fire can be brought upon the point of attack (Fig. 16).

These batteries are located in rear of the line of outposts, and at distances varying from one to two miles from the point of attack, depending upon the nature of the ground and the strength of the works to be attacked.

They are so arranged as to bring strong direct and enfilade fires upon all parts of the works which, with their fire, sweep the ground in front of the point of attack, and are, if possible, so placed as not to interfere with the siege operations that are to follow.

In selecting the sites for these batteries, care should be taken that, while the batteries are within effective range of the point of attack, there shall be no interruption in the work of their construction by sorties of the garrison, or by drawing the fire of the work upon them. They should be far enough from the work to make it a difficult thing to stop the construction by a sortie, and screened in such a manner as to hide their exact positions from the enemy until they are ready to open fire. It is recommended to locate some of the batteries so that their guns may be usefully employed during the entire siege.

To avoid the concentration of a heavy fire upon a group of batteries and crippling the fire from them, they are separated, and each battery armed with but few guns. From four to six guns will generally be sufficient for each battery, and will not be so liable to draw a concentrated fire as when

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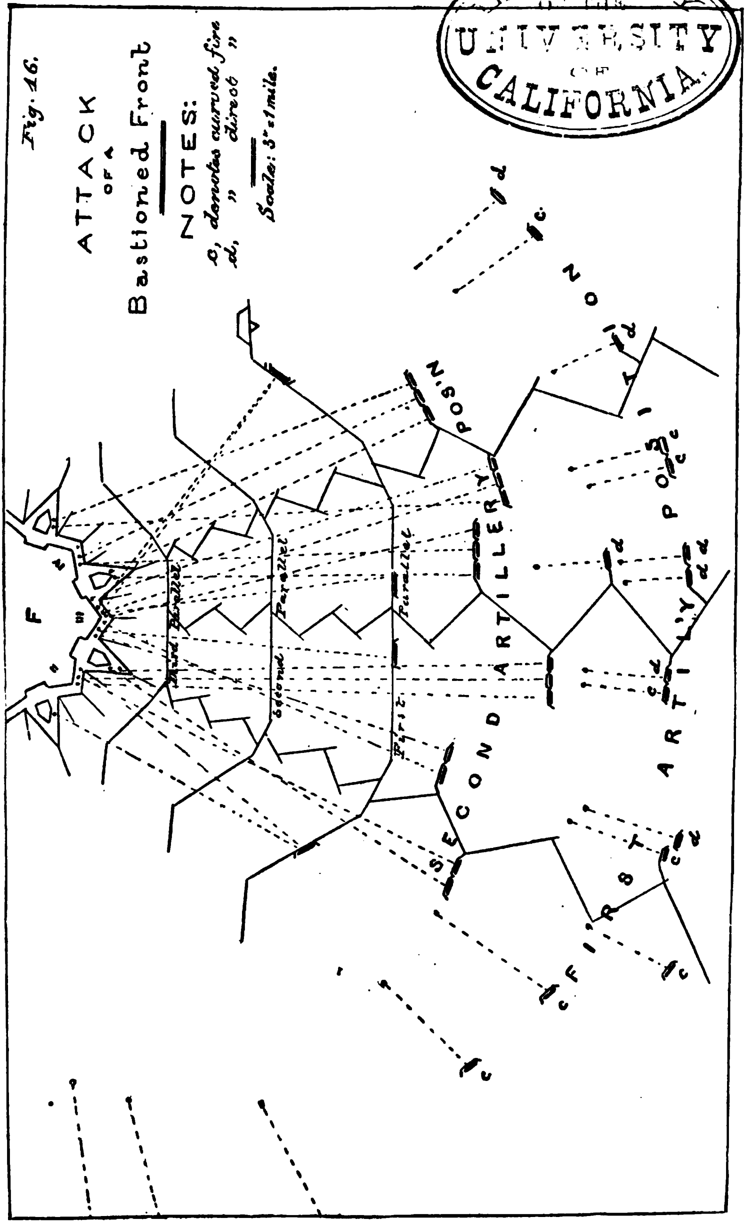


there is a larger number in the same battery. The batteries, when finished, are armed and supplied with ammunition. When all is ready, a day is fixed, upon which all of them are to open fire upon the work.

During the night before this fire is opened, all screens which interfere with the firing should be removed; and also objects near them which might afford assistance to the besieged in determining the range of the batteries should be destroyed or leveled.

Places should be selected from which observers could note the effect of the fire of the batteries, and these points should be connected with the batteries and with the head-quarters by a system of signals or by telegraph. Steeples of churches, high trees, or temporary stands like these used in signalling, may be employed as observatories, in which an observer can be placed with a strong field glass, or good telescope, to watch the effects of the shots and to observe the range of fire.

Balloons have been suggested as useful for this purpose, and, in the future, may be more or less used. The difficulty of keeping them stationary, and preventing them from having a twisting motion, has interfered, so far, with their usefulness for observing with the accuracy needful for this purpose.

39. Opening of the Fire from the Batteries.—At daylight upon the day fixed, the batteries, at a given signal, open fire upon the point of attack. Effort should be made to watch carefully the first shots, and to make the corrections in direction and elevation as quickly as possible.

The firing will be continued during the day, in accordance with such instructions as may have been given as to the number of rounds to be expended, rate, etc.

The firing will be kept up during the night, but will not be so heavy, since its object will only be to prevent repairs being made to the embrasures, and guns being remounted, which otherwise would be done, if the firing ceased.

As soon as the superiority of the artillery attack becomes evident, the outposts are pushed forward and made to take up a position nearer the work. This position will be intrenched, and its communications with the rear made safe. Finally, when the fire of the besieged has weakened sufficiently to allow it, the outposts gain possession of the ground on which the first parallel is to be made.

40. Construction of First Parallel.—It is supposed, in what precedes, that the garrison has been contesting the advance of the outposts, but that now, from their steady advance and from the heavy converging fire of the batteries, the defenders have all drawn back and within the fortifications. Also, that the superiority of the attack will prevent material interference with the work upon the parallel.

The first parallel, at this stage, is then traced and executed by simple trench or flying trench-work, as described in Articles 7 and 8; or it may be made by joining and widening the shelter trenches used by the outposts. The outposts are then strengthened, thrown forward a short distance, and employed as a covering force to protect the parties at work in the trenches.

A short time before day-break, the working parties are relieved from duty in the trenches and sent to the rear. The covering troops fall back behind this line of partially constructed trenches, leaving in them a line of sentinels as guards, who watch the ground in front. The covering troops shelter themselves with whatever cover they can obtain, and by lying down upon the ground. The line of these troops will be at a short distance from their sentinels, and the support to this line will not be so far but that they will have time to reach the trenches as soon as the enemy can, if a sortie is attempted.

As soon as the trench is finished the covering troops take possession of it, and are then known as the "guard of the trenches." The guards of the trenches are usually relieved once in twenty-four hours, the hour for the relief depending upon the safety and the convenience of making the movement. The engineers are relieved at times intermediate with the working parties.

In connection with the subject of reliefs, it may as well be stated that complete organizations, as companies and regiments under their own officers, are found to give more satisfaction than mixed detachments. Also, that when working parties are small in numbers, short reliefs can be employed with advantage. But when very large working parties are required the frequent changes incident to short reliefs are productive of confusion, and are not worth the risks to be run by using them.

41. Extent of First Parallel, and Distance from the Point of Attack.—In the sieges of the past, where the arms used were smooth-bored, the distance of the parallel was about 600 yards from the point of attack. This placed the working parties just out of the range of the grape-shot, and made them safe from any great loss from the enemy's fire, even if discovered, as this fire was inaccurate. The distance to be taken at the present time follows the same general rules. That is, to place the parallel as near the point of attack as possible, but not near enough to expose the working parties to heavy loss from the enemy's fire. In the presence of a vigilant enemy, supplied with improved artillery and small arms and furnished with means to illuminate the ground, it would not be expedient, nor probably practicable, to begin the first parallel at a distance less than 1,000 yards from the point of attack. It is probable that the distance may have to be greater, but this will depend upon the cover to be obtained for the working parties, and upon the vigor of the defence.

We find that the English opened their first parallel at Sebastopol at about 1,800 yards from the point of attack, and the French opened their parallels at 1,000 and 1,800 yards, respectively.

In the attack upon Fort Wagner, in 1863, General Gillmore opened the first parallel at a distance of 1,360 yards.

One thousand yards may, therefore, be considered as the least distance which can be used, excepting under very favorable circumstances.

The extent of the first parallel must be sufficient to embrace the entire field of attack. Suppose an attack to be made upon a place, **F** (Fig. 16), fortified upon the bastioned system, and bastion **III** to be the point of attack. The collateral bastions, **II** and **IV**, and the demi-lunes in front of the adjacent curtains bring a strong fire upon the ground over which the besiegers must approach. There is also a fire upon this ground from the further demi-lunes adjacent to the bastions **III** and **IV**.

The parallel should extend at least far enough to reach the prolongations of the capitals of the adjacent bastions, **II** and **IV**. If strong enfilading batteries can be placed to keep down the fire of the farther demi-lunes the parallel need not extend beyond the lines just named, otherwise it were better to include them. The extremities of the parallel are sometimes thrown back and arranged so as to furnish a fire in the direction of the flanks, as shown in the figure. The extremities of a parallel should rest upon strong points of defence, either naturally strong, or made so by means of field works.

42. Approaches.—There should be, in the systematic attack, at least three approaches, when the point of attack is similar in character to that shown in Fig. 16. These approaches should be along the capitals of the works attacked; in this case, upon the capital of bastion **III**, and upon the capitals of its adjacent demi-lunes. The object of running the approaches upon these lines is to reduce the exposure of the trenches to the direct fire from the works, and to be as much as possible out of the way of the attacking batteries.

The approaches are run forward in zigzag directions, as previously described, having the prolongations of each branch to fall to the right or to the left of the place, and about 100 yards from it. Each branch overlaps the branch behind it by about ten yards, to defilade it from the enemy's fire. This overlap is further utilized by making it a depot for trench materials, and for other purposes.

43. Batteries of the Second Position.—As soon as the first parallel and the approaches to it from the rear are finished, attention is directed to the construction of the batteries of the second position. The distance of a battery from the work and its position depend largely upon the nature of the ground and upon the object to be attained by its fire. Where injury to scarps, etc., is intended, by a curved fire from pieces firing at high angles of elevation, it is evident that the guns must not be too near the work, or they will not effect anything. Where the batteries are to fire over troops in the parallel, they should be placed from two to three hundred yards in rear of it. Some of the batteries should be placed in the first parallel, or slightly in advance of it.

It will be seen that a part of the batteries using curved fire may be retained in the position first taken, but those intended for direct fire must be moved nearer the work.

The parapets of the batteries of the second position are made thicker than those of the first position, and should be screened during the process of construction. This can be done by means of trenches made in front of the batteries. If it can be done, it is better to construct the battery and arm it in a single night, than to trust to its being hidden by a screen from the enemy's view in the day time.

When the batteries of the second position are ready, the fire is opened, as before described for the batteries of the first position. The guns being so much nearer, and the superiority being upon the side of the besiegers, it is supposed that the effect of this fire will be to silence that of the besieged.

44. Advance from the First Parallel.—The artillery fire of the front being practically silenced, the approaches are pushed forward by the simple trench, or by flying trench-work. When the advance is within something less than half-way between the first parallel and the salients upon which the approach is made, say fifty yards, the approaches are connected by a trench, generally parallel to the line of the first parallel. This must be quickly executed, as the workmen are within the range of musketry fire. It becomes necessary in the construction of this parallel to employ the method of "flying trench-work," as a means of more quickly obtaining shelter. The trench thus constructed is known as the **second parallel.**

It is placed for tactical reasons nearer to the first parallel than to the work, so that if a sortie be made by the besieged to drive away the working parties, assistance can reach the latter in time to help them to repulse the sortie.

45. Advance from the Second Parallel.—Upon advancing from the second parallel, it may be possible, under favorable circumstances, to construct the approaches for a short distance by flying trench-work. If it can be done without much loss this method is recommended, on account of the rapidity of the advance in this way, as compared with that gained by sapping.

It is very doubtful, however, if this method can be used, if the defence is a vigorous one, since the workmen are within range of musketry. The approaches will, in all probability, have to be made by sappers, who will have to use the single or double sap. When the heads of the approaches reach the foot of the glacis, or are within a distance of from 100 to 60 yards from the salients of the covered way, the approaches are connected by a trench, which is called the **third parallel.** This parallel must be constructed by sapping.

The nearness of the third parallel to the covered way makes it possible for troops occupying the parallel to carry the salients of the attacked work by an open assault—a thing not possible before, if the defence be at all a vigorous one. The completion of the third parallel forms the close of the second period of attack.

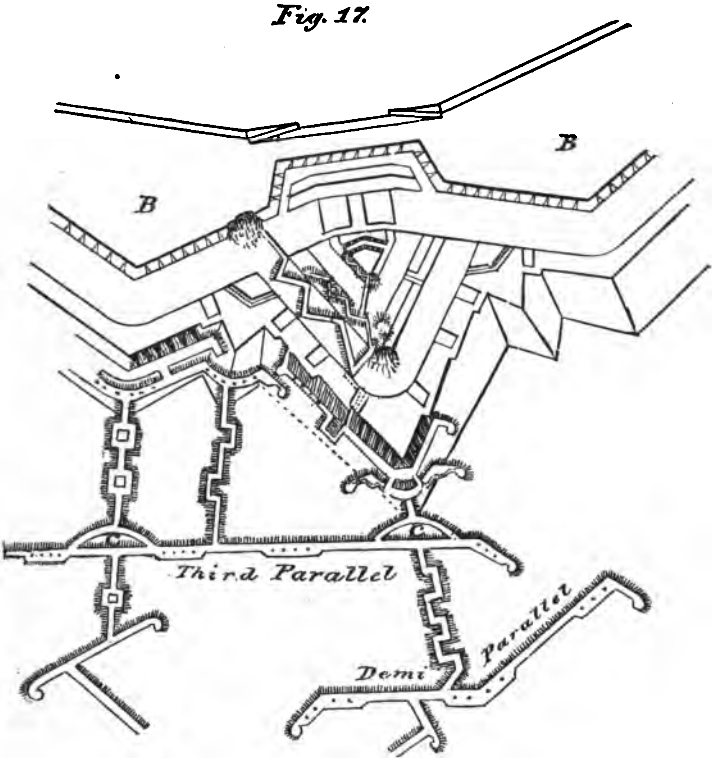
Sometimes the attack is divided into two parts, the **distant** and the **close attack.** The completion of the third parallel forms the dividing line; all operations after its construction being classed under the head of the close attack.

46. Demi-Parallels.—It will be seen that, from the nearness of the third parallel to the work, it will not take a long time for the sappers to reach a point nearer the work than they are to the second parallel. To give the sappers the necessary support as they run their saps forward from the second parallel, it is usual to construct trenches known as **demi-parallels.** These demi-parallels are placed about half-way between the second and third parallels, and are made from 100 to 150 yards long, depending upon the number of troops to be posted in them (Fig. 17).

To add still further to the protection of the sappers, sharp-shooters are sent forward in advance of the saps for a distance of thirty or forty yards. These sharp-shooters entrench themselves in rifle pits, and keep up a constant fire on all points from which a fire can be brought upon the sap.

47. Arrangement of the Third Parallel.—The nearness of the third parallel to the work brings the besiegers within close range of the enemy's small arms. Arrangements by which this deadly fire of the enemy may be kept under are more necessary now than at any previous time. Loop-holes, formed of sand-bags or other means, must be provided along the crest of the parallel, and these manned by men skilled in firing. As sorties may be frequently attempted, and as it may be expedient to sally forth from the trench to meet them, or to take advantage of their failures, the interior slope of the parallel should be arranged with suitable steps,

Fig. 17.



which can be used by the guards to sally forth from the trenches.

48. Advance from the Third Parallel.—In former times, the difficulties of a siege may be said to have begun with the advance from the third parallel. The besiegers were then upon ground specially prepared for defence, and were still separated from the besieged by steep scarps, or by wet ditches. A succession of obstacles placed in the way of the besiegers' approach had to be overcome, and these operations performed under an enveloping fire of small arms.

In the days of smooth-bores it was only during this period that the fire of small arms was really effective, because of the small range of the piece. The use of rifled pieces has given the besieged better chances to delay the saps, to hinder the construction of breaching batteries upon the glacis, to prevent the passage of the ditch, and to resist lodgments being made in the breaches, all of which were formerly difficult operations. These improved means of resistance have compelled the besiegers to break down, and to practically silence the fire of the work, before they can finish the third parallel. The result has been, in the sieges of the present day, that by the time the besiegers have reached the glacis, the garrison, exhausted by their labors, shattered and worn out by the superiority of the besiegers' fire, and discouraged by their failure to keep the besiegers back, surrender the place.

Supposing that the contest is still to be carried on, the first operation, after leaving the third parallel, is to drive the enemy from the covered way, and to form a lodgment upon the crest of the glacis. This act of forming a lodgment in this place is known as the **crowning of the covered way.**

Supposing there are no countermines—for if there were it would be necessary to resort to mining to destroy them before the lodgment could be undertaken—the covered way may be crowned either by making a regular approach, or by an open assault. If the defence is vigorous the latter can only be effected by an enormous loss of life, and is not recommended.

49. Crowning the Covered Way by Assault.—The crowning of the covered way by assault may be attempted from the third parallel, or after a partial advance by sap had been made from this parallel.

The storming parties are carefully selected, and are placed in the trenches from which they are to go forth to the assault. The trenches are prepared with steps to allow the men to go over the parapet with whatever front is used. The advance is made by skirmishers, followed by the main body, and reserves. A party of sappers in charge of engineer officers accompany the main body to clear away all obstacles in the way of an advance.

The assault may be made during the night, or just before dark. The latter hour is usually preferred. A rush is made for the covered way, and an effort is made to cut off all communications leading to the ditch, to intercept the retreat of those who are in the covered way, and to prevent assistance reaching them. The skirmishers shelter themselves behind traverses, or anything which affords cover, and keep up a brisk fire upon everything showing itself upon the parapets.

Working parties, with gabions and the proper intrenching tools, follow closely the main body, and are posted on each side of the salient and along the covered way for a distance of about fifty yards. These parties, under the direction of the sappers, construct a trench by the method of the flying trench-work. As soon as the trench is completed the working parties are withdrawn and the troops are posted in the trench. This completes the operation of "crowning the covered way." Sappers connect this trench with the third parallel by approaches.

50. Crowning the Covered Way by Sap.—The former method is a very bloody one, when the defence is at all vigorous, and is more apt to fail than to succeed. Even if successful, it must be accompanied by great loss of life, as before stated.

For these reasons, engineers prefer the slower but safer method of proceeding by the sap.

The approaches as far as the third parallel are made in zigzag directions, each branch having its prolongation to fall outside the work a distance of 100 yards in the beginning, and from 20 to 30 yards when near the third parallel, to guard against enfilade fire.

These zigzags are not practicable after leaving the third parallel, and the approaches are directed straight upon the work. This direction of the approach requires that it should be defiladed, to protect those using it from the enfilade and reverse fires to which the trench is exposed.

The defilade is effected by means of traverses (Art. 15), and the sap used will ordinarily be the double sap (Art. 13). This mode of approach is ordinarily known as the **traversed sap,** and may sometimes have to be used even before reaching the third parallel.

51. Circular Place of Arms.—In advancing from the third parallel, it is usual to break out at points about sixty yards on each side of the capitals of the salients upon which the approaches are directed. The saps are run so that the trenches will come together about fifteen or twenty yards in front of the third parallel. The saps may go forward in straight lines, but frequently it is more convenient for them to follow a curved line. When this curved direction is taken, this part of the trench is known as the **circular place of arms** (*c*, *c*, Fig. 17).

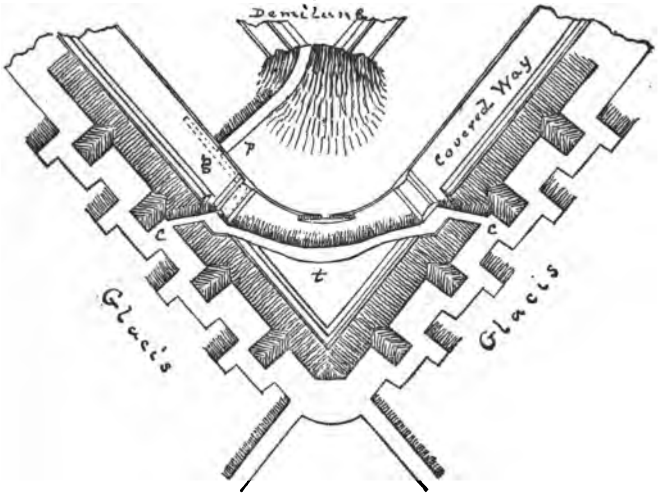
From these circular places of arms, the approach is pushed forward by double sap until within about thirty yards of the salient attacked. At this distance, saps are run to the right and left forming demi-parallels (Fig. 17), in which troops are posted to act as guards, and to bring an enfilade fire upon the covered way.

These demi-parallels are sometimes extended and connected, forming another parallel for the use of the besiegers.

In former sieges it was usual to take some twenty or thirty yards in length of these demi-parallels from near the points of intersection of the trench with the prolongations of the crests of the covered way, and raise the parapet to a height of ten feet. This command of ten feet gave a plunging fire into the salient places-of-arms, by means of which the defenders were driven out of them.

These raised portions were known as **trench cavaliers.** They were difficult to construct, consuming much time, requiring a great deal of labor, and being attended with considerable loss of life. They are easily destroyed by the enemy's fire, and are not so serviceable now as they were formerly. They will be rarely, if ever, used in future sieges.

Fig. 18.



52. Lodgment upon the Crest of the Glacis.—As soon as the salients of the covered ways have been cleared of their defenders, the approaches are pushed forward until within six or eight yards of the crests. The approaches are then carried along on both sides of the capital, and parallel to the crests, until the requisite length of trench is obtained. This construction completes the lodgment upon the glacis (Fig. 18).

If there be danger of the defence making an attempt to recover the salients, it is advised to run a sap across the places of arms, connecting the ends of the sap with the lodgments on the glacis (*t*, Fig. 18).

53. Breaching the Scarps.—The successful crowning of the covered way gives the crest of the glacis into the possession of the besiegers, and enables them to build batteries in positions from which the scarps can be seen.

Having possession of the crest of the glacis, there are only the ditch and its walls between the besiegers and the adjacent work, whatever it may be.

If both sides of the ditch are protected by revetment walls, it will be necessary to make arrangements for a descent into the ditch, and to provide means for overcoming the obstacle to an assault afforded by the scarp wall. The counter-scarp and scarp walls may both be thrown down by the operation of mining, and thus the obstacles in the way of an assault be removed. The objection to this method consists in its uncertainty and its slowness.

The method usually followed is to make the descent into the ditch by means of **grand galleries** (constructions used in mining operations), and to batter down the scarp wall by artillery fire.

The construction of the galleries and of the breaching batteries are begun simultaneously.

A **practicable breach** in a wall or parapet is one which is wide enough to accommodate the front of the storming party, and which is provided with an easy slope by which this party can quickly ascend.

The least width of a practicable breach should not be less than twenty yards, and the slope leading to it should not exceed thirty-five degrees. In the ordinary retaining wall, it is considered necessary to knock down something more than half of the wall, and in a detached wall, about three-fourths of it, to get material enough for this slope.

The method formerly used to breach a wall, and described in works upon "gunnery," was to make a horizontal cut about one-third of the height of the scarp wall from the bottom of the ditch, and, at the extremities of this horizontal cut, to make vertical cuts extending to the top of the wall. This being done, a few additional shots fired into the mass brought the wall down.

It is considered to be a better method at the present time to begin at the top and batter the wall by successive layers, until the débris is sufficient to form a practicable slope leading to the breach. By this method the masonry is broken into smaller fragments, and the breach is more practicable for an assault.

Most of the breaching may be effected by heavy guns occupying the second artillery position. The breaches thus made are hardly ever practicable, and it will be necessary to construct batteries along the crest of the glacis to make them so.

By the time the breaches are finished the galleries leading to the ditch should be completed.

54. Descent into the Ditch.—The descent into the ditch will be made by the grand galleries, which were begun at the same time the breaching batteries upon the glacis were commenced. These galleries are so situated that their exits into the ditch will be nearly opposite one of the extremities of the breach. The extremity furthest inwards will usually be selected when the breach is in the face, although there are occasions when the other extremity will be more suitable.

The slope of the gallery is taken so as not to exceed one upon four ($\frac{1}{4}$), and the gallery is located so that the bottom of the gallery will intersect the face of the counterscarp wall at a given distance from the bottom of the ditch, if a dry one, and from the surface of the water, if the ditch is a wet one.

In dry ditches, this intersection will be at the bottom of the ditch, if there is to be no sap run from the gallery; if there is to be a sap, the distance is taken from three to four feet below the bottom. In a wet ditch, the intersection will be about one foot above the level of the highest water.

These grand galleries are similar in construction to those described in "military mining."

The construction is begun by sinking a shaft, ten feet square, for a distance of ten feet below the surface of the ground, to form an entrance to the gallery. The bottom of the shaft and the bottom of the lodgment upon the glacis are connected by a ramp cut down into the shaft.

The shaft is made ten feet deep, so as to leave three feet of earth above the capsill of the gallery frame forming the entrance to the gallery, this frame having a height in the clear of six feet and six inches.

The gallery is completed as far as the back of the counterscarp wall. When the breach opposite to it is made practicable, it is finished by breaking through the counterscarp wall. Some explosive, or manual labor, is used to remove the wall in front of the exit.

It has been found useful in some cases to extend this gallery a few yards behind and along the counterscarp wall, and to open loop-holes in the wall, forming a counterscarp gallery for musketry (*g*, Fig. 18).

55. Passage of the Ditch.—The passage across the ditch will be easy enough if it be a dry one, and the besieged are not able to occupy the breach.

The crossing may be made by a sudden rush, or by means of sapping. The latter is the method to be adopted if the defence is still vigorous, for the reasons already given in the remarks upon crowning the covered way.

If the ditch is a wet one, the passage is more difficult and more tedious. The student is referred to the Manuals of Engineering for the details of the devices and methods used in this case. The general principles involved in the methods used require the construction of a bridge, or of a solid dam with a broad upper surface, for the passage of the assaulting columns. The difficulties of construction are very great, and can be appreciated when it is considered that the workmen are exposed to a fire sweeping the ditch, and may have to meet strong currents and frequent changes of level in the water of the ditch.

56. Lodgment upon the Breach.—If the besieged contest the possession of the breach, it has to be gained and a lodgment made upon it, either by assault, or by gradual approaches. When carried by assault, the arrangements made differ but little from those described heretofore. When gained by gradual approaches, the sap is carried up the slope and then along the crest of the breach by sappers, who are protected from the besieged by the fire from the lodgment in their rear on the glacis. As soon as the trench along the crest is completed, it is occupied by troops, and the lodgment is effected.

The trench upon the breach may be extended across the terre-plein of the work, as recommended for the salient place of arms; or it may be pushed forward along the faces of the work.

57. Attack of an Interior Work.—The methods pursued thus far are supposed to have resulted in placing the besiegers in possession of the salients of the demi-lunes and bastion of the front of attack.

At this stage of the operations the works will be either surrendered or abandoned. If they are not, it is probable that the besiegers will have their further approach contested by a defence made behind permanent or temporary retrenchments, cavaliers, or citadels.

These interior works may be so strong as to require as much labor and time to take them as have already been expended upon the bastion and its outworks. From the great difficulty experienced in bringing heavy guns into positions close enough to breach these interior works, it may be possible that the besiegers will have to use "mining operations" to break down the walls; otherwise, the same general methods already described for the attack of the bastion, will be used in the attack of interior works.

58. Attack of an Intrenched Position.—The methods described have been those used in the attack of a single fortification and its outworks. If it be supposed that the attack is to be one upon an intrenched position, where the main work is surrounded by a chain of **detached works**, and the intermediate space is used as an intrenched camp (Fig. 19), it is seen that the operations are more difficult and more complicated than in the case of the single fortification.

An attack of the main work, F (Fig. 19), is not practicable until the besiegers have broken through the line of detached works. The attack of any one of the detached works is made more difficult by the assistance it receives from the adjacent works. In addition, since the garrison of any one of the detached works is only a small fraction of the entire force occupying the intrenched camp, this garrison can be easily and quickly reinforced at any time. As a consequence, a more obstinate resistance can be made to the occupation of the ground in front of a work than that supposed in the attack of a single work, and more powerful sorties can be made to interrupt and delay the progress of the siege operations after they have begun.

In Fig. 19 the detached works are supposed to be about one mile apart, and this line of works to be about two miles in advance of the main fortification.

Supposing the attack to be made on the side shown in the

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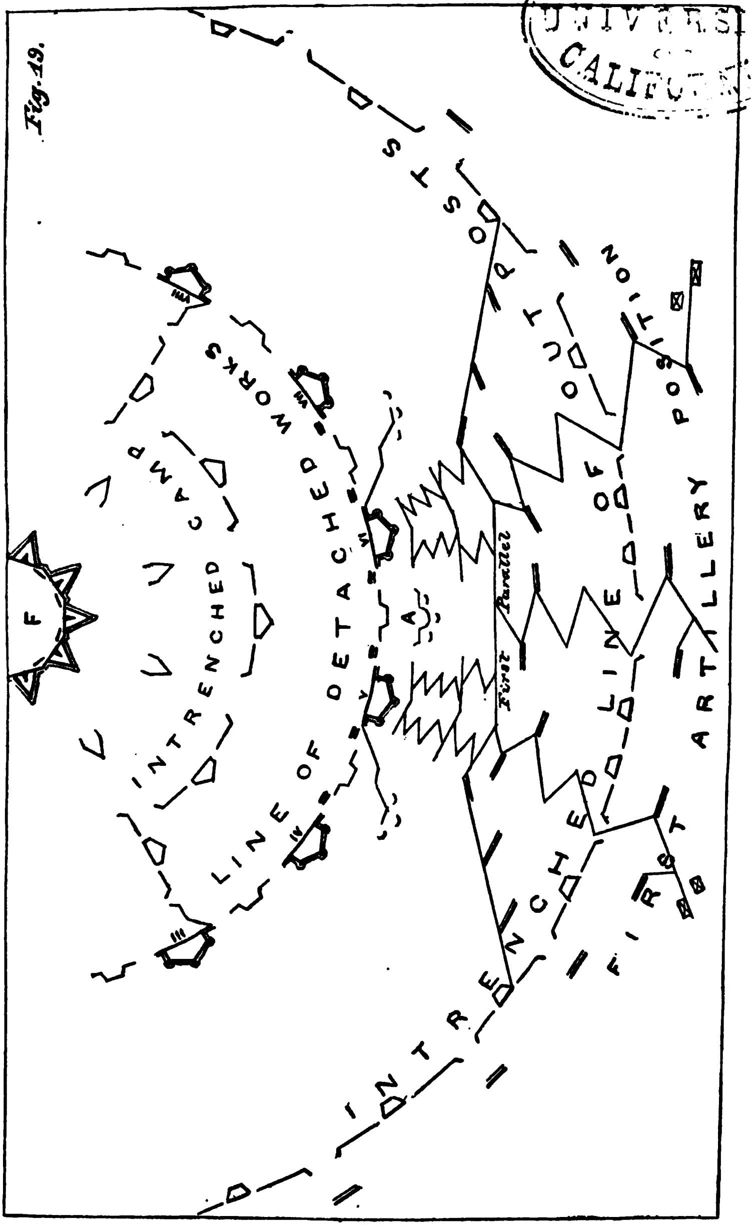
Fig. 19.



figure, it will be seen that the besiegers will have to capture forts **V** and **VI**, and silence **IV** and **VII**, before they can break through the line at **A**, and move upon the intrenched camp. It is possible that even the capturing and silencing of these four works would not be sufficient to allow an advance with safety, and it might be necessary to capture others before the advance could be safely made.

The investment of an intrenched position of this kind becomes an operation of great magnitude, in consequence of the great length of line to be occupied, and the large number of troops necessary to defend it.

Nevertheless, the general methods already described are used in the attack of such a position, and they differ only in being upon a much larger scale. The general methods are indicated in Fig. 19.

59. Vauban's General Rules.—Marshal Vauban, the great military engineer, had a larger experience in conducting sieges than any other man of his time, or since. From his extensive experience he laid down certain general principles to be observed in making an attack by the method of regular approaches. The following rules are based upon these principles.

VAUBAN'S RULES.

1. Not to begin work upon the approaches until the besieging forces are well posted, and everything is in a state of readiness to prosecute the work.

2. A single attack is better than two which are independent of each other.

3. The parallels should embrace the entire field of attack.

4. There should be at least three parallels, and these placed in positions best for mutual support.

5. The greater the number of approaches, the better they will be for communications, and the less danger there will be of an interruption of the communications.

6. Approaches should never be run upon a narrow front, nor on causeways, nor in marshy ground.

7. Approaches should not be pushed forward until the trenches in their rear which flank them have been completed and occupied by troops.

8. The approaches must be kept free from trench materials, or anything which would prevent free movement of bodies of men passing through them.

9. Ricochet batteries should be so posted as to get slant, reverse, and enfilading fires upon the line at which they are to fire.

10. The fire from the batteries should be opened simultaneously.

11. It is better to drive the besieged out of the defences by the fire from the batteries and from the parallels, than to attempt to do so by open assaults.

12. If an open assault is to be made, it should be made in day-light, if the fire of the defence is silenced; if not silenced, the assault should be made during the night.

13. Sorties made upon the head of the sap should be repelled by fire from the parallel in its rear, the besiegers keeping under shelter of the parallel.

14. A sortie being repulsed, and an attack being made by the bayonet, care should be taken that the attacking party do not follow success too far, but have time to regain shelter in the trenches before the besieged can fire upon them from the works.

The foregoing rules are still applicable, and the methods already described are in accordance with them.

CHAPTER IV.

DEFENCE OF A FORTIFIED POSITION.

60. Relations of the Defence to the Attack.—Military writers have generally assumed that no operation of war is more certain of success than that undertaken by a siege. The grounds for this assumption were the ease with which the besiegers could be reinforced while the besieged could not be, and the inequality of the struggle, the besiegers largely outnumbering the besieged.

This assumption, however true in the past, may not be true for the future, and the predictions of a successful termination to a siege may not be fulfilled. Modern arms of precision, improved projectiles, the uses of electricity, and other improvements in warfare, have added greatly to the destructive measures of the besiegers, but, at the same time, have given to the besieged powerful resources which can be used in the defence, so that the result of the struggle will be far from certain. A position strongly fortified, fully garrisoned and supplied, and *well commanded*, may resist the operations of a siege for so long a period as to be considered impregnable.

61. Garrison.—The numbers and kinds of troops to be used to garrison a fortification depend upon a great many things. The kind of defence, whether it is to be an active or a passive one, materially affects the numbers to be used.

A more numerous body of troops is necessary when an active defence has to be made, than would be required to simply retain possession of the position for a limited period.

Where a serious attack is to be expected, it is laid down as a general rule that there should be at least one infantry soldier for every yard of interior crest of the portion of the works liable to be attacked, and in addition a reserve equal to one-third, or one-fourth, of the number thus determined. There should be of artillery troops enough to man the guns, and of engineer troops to superintend the defensive operations and perform the labors imposed upon their branch of the service. When the position is one of some extent, a small body of cavalry should be added to the garrison.

Taking a small detached work with a caponnière, as an example, and supposing this work to have a front of two hundred and fifty yards, with ten guns in the caponnière, and twenty-five on the parapets, the following estimate of the numbers of the garrison is given: Four hundred infantry, two hundred and fifty artillery, and fifty engineer, soldiers; making a total of seven hundred men.

If the fortification is a bastioned one, with scarps thirty three feet high, there would be about four hundred and fiy- yards of interior crest in one of its fronts. The number of infantry and the number of guns to arm the fronts are easily estimated, and the infantry and artillery portions of the garrison are determined. One-twentieth part of the infantry has been considered as advisable for the number of engineer troops. For an intrenched camp, there would be, in addition to the garrisons of the detached works and of the main enceinte, a force in the camp. The strength of this force would vary with the length of front to be guarded. A force of one thousand men with a reserve, for each mile of front, would be needed for this purpose.

What numbers there should be in a garrison to be most usefully employed, cannot be given accurately without the strength of the works, kinds of armament, and the objects to be gained by holding the works, are all known.

62. Armament.—A permanent fortification rarely has all its available guns mounted before an attack is made.

The faces, flanks, and outworks, as a general rule, are armed only to guard against surprise, or assault.

For this purpose, supposing a bastioned front to be the work considered, three guns in the salient of the bastion, two on each flank, and one in the salient of the demi-lune, would be the least number that should be mounted to guard against surprise.

The number of guns on hand ready to be placed in position should be enough to allow one gun for every twenty yards of interior crest bearing upon the field of attack, and still have enough left in the other parts of the work to render those parts secure against assault.

When detached works are employed, the full armament is usually mounted as soon as the fortification is occupied.

The kinds and calibres of the guns used will depend upon the defence to be made. Fortifications upon the sea-coast being exposed to fire from heavy guns, are furnished with armaments much more powerful than those situated inland, and which are exposed to attack only from siege guns. Experiments are still being made to ascertain the best and most powerful gun with which to arm these fortifications.

In addition to the heavy guns, there should be several batteries of field guns within the works, when a siege is anticipated. Also, there should be on hand a reserve of gun-carriages, and sufficient means to move the heavy guns from one place to another.

Engineer tools and materials should be in store, and ammunition enough to last the entire period of attack.

All these, of course, are supposed to be included under the head of "fully supplied."

63. Defensive Preparations.—There are certain things necessary to be done in the anticipation of an attack, notwithstanding the fact that the fortifications may be strong, the garrison efficient, and the supplies ample. The principal preparations may be stated to be as follows:

1. To clear the ground exterior to the fortifications of all obstructions which would afford shelter to the besiegers, within range of the works.

2. To put in a state of defence those points exterior to the works which are to be occupied in the event of a siege.

3. To make arrangements for interrupting and destroying all lines of communication which might be of service to the besiegers in the attack of the position.

4. To complete and arm the batteries, and to construct the field works, which may be necessary to reach ground not seen from the fortifications.

5. To mount additional guns upon the parapets, and to lay additional platforms for guns at those points where they will be required at a later period.

6. To construct traverses, to trim the slopes of the traverses already built, and to give to the interior slopes their proper inclinations.

7. To construct casemates for the guns and mortars, and to build bomb-proof shelters.

8. To put in order the drawbridges, batteries, etc., and to arrange for the defence of the posterns.

9. To construct galleries and mines, if countermining is to be used.

10. To arrange the entanglements, abatis, torpedoes, etc., forming the accessory means of defence.

11. To provide a good system of signals, and to prepare all the electrical apparatus which will be necessary.

64. Memoranda Furnished to a Garrison Exposed to an Attack.—Instructions are usually given to the commanding officer of each work, as to the course he is to pursue in case of attack. As an example of such instructions, and in illustration of the preparations required and precautions to be taken by the defence, the following memoranda, issued to the officers serving in the defences surrounding Washington City in the war of 1861–4, are taken.

Memoranda compiled for the guidance and information of officers serving in the defences of Washington:

"1. The number of men required for the garrison of each work (artillery and infantry supports included) has been calculated, and should be known to every commanding officer of a fort; but it will be for the brigade and division commanders, or for the commanding general, to determine the necessity of filling up each garrison to its full siege complement and of manning the connecting lines of rifle-trenches.

"2. It is the duty of a commanding officer of a fort to see that he has all the means and appliances that may be wanted during a siege provided beforehand. If his position be somewhat isolated and where the enemy may cut off his communications, he should see that he has an ample supply of provisions stored, either in his fort, or in a secure place in its rear; and he must take measures to keep an abundant supply of water in the fort, both for the use of the garrison and to extinguish fires.

"He should see that his fort is provided with all the tools that may be wanted during the siege, particularly with shovels, picks, axes, saws, augers, and hammers. Further, he should provide, either beforehand or as soon as possible after the siege commences, all the materials that may be wanted during the siege, such as an abundant supply of timber, of planks, of nails, spikes, of sand-bags, gabions, and fascines. Timber is of the first importance; a large supply of it should therefore be secured.

"3. When any part of the line of defence is threatened with an attack, all houses, trees, bushes, and in general everything that could be used as a cover by the enemy's sharpshooters, should be at once removed for a distance of at least six hundred yards from the line. If sharpshooters can be concealed within that distance of a fort or battery, they will pick off the cannoniers, and the guns cannot be served without serious loss.

"In conducting the defence of a fort, each company, or detachment, should have its particular post and duty assigned to it, and receive special instructions as to their duties in all possible contingencies.

"Commanding officers should be careful to see that all their subordinates thoroughly understand the ground, both in their front and rear, and are familiar with all the roads and paths; they should know by a careful examination of the ground in front the points which an enemy would select for batteries, and the exact ranges to such points, and should study out how best to arrange their own guns to contend with such batteries, should they be erected; they should know the relations of the fort they occupy to the adjacent works, and be familiar with all the resources that may be made available during the defence. This information should be imparted by them to the non-commissioned officers, and in some cases to the privates; for it should be remembered that the fate of the fort may depend upon the good or bad conduct of one individual.

"There should be a reserve in all cases. It should be posted in the bomb-proofs, or behind traverses and magazines, or under temporary shelter made by leaning timber against parapets, magazines, and bomb-proofs, or by digging trenches in the ground and covering them with timber and earth.

"Strict vigilance should be exerted to guard against surprise; for this purpose, when the enemy approaches, a chain of sentinels should be posted in front of the works, and as far to the front as practicable, taking particular care to have them posted at all points where an enemy might approach the works without being seen, either for the purpose of reconnoitering, or delivering an assault; but the general arrangement of sentinels must be made by brigade or division commanders.

"By keeping up, both by day and night, such a chain of sentinels in front of the works, and by posting, where practicable, a few sharpshooters in holes or rifle-pits in front of each fort, the efforts of the enemy to obtain the information he wants before commencing the siege batteries will be greatly retarded, and time afforded to the defender for completing the preparations to receive him.

"If the sentinels are driven in and an attack is apprehended at night, fire and light balls should occasionally be fired to the front, taking care, however, not to set fire to the abatis; and, in this case, the guns should be double-shotted, and pointed, if possible by daylight, so as best to sweep the ground within a distance of six hundred yards, depending on the configuration of the surface in each particular case.

"If the ditches are not flanked, shells loaded with service charges and ten-second fuzes, should be placed on the banquettes, in charge of men specially instructed how to use them. These men should be provided with pieces of burning slow-match.

"Hand grenades, loaded and capped, should also be placed ready for use; and, finally, the men should sleep at their guns, and every man should know his post and his duty. Shells and also hand grenades may be exploded by attaching a string in such a way that the act of rolling them or throwing them will, as soon as the *string* is brought *taut*, explode a percussion cap or friction tube.

"4. If the enemy should open his attack by a warm cannonade, and concentrate his fire upon a particular fort, the troops should not be unnecessarily exposed to it, if they can be sheltered near the posts they are to occupy when an assault is made. If the cannonade should become too warm for the garrison to reply without too much loss, the field and siege guns should be removed from their embrasures and placed behind the parapets, or, in case of an enfilading fire, behind traverses, bomb-proofs, etc.

"During a cannonade the dead and seriously wounded should be kept out of sight.

"When the assault is made, this cannonade of the enemy must cease in order not to injure his own troops. The guns are then run into position, and every man resumes his post. The men should be instructed to reserve their fire until the enemy has arrived at certain points, marked out in front of the works, where it will be most effective.

"Particular attention should be given to securing the gateway. The abatis in front should be made continuous. As the gates are made to open inward, the enemy cannot easily open them outward. The danger to fear is that he will force them inward, or lift them off their hinges. To prevent the first, roll a heavy log against the inside of the gate, plant posts or drive strong stakes behind it, and, for greater security, cover the log with earth. The second danger may be prevented by "upsetting" the head of the pintle upon which the gate turns, or still easier by driving a strong spike immediately over it. If the gateway is not flanked it may be necessary, in some cases, to increase the dirt over the log until it becomes an infantry parapet. Communication with the interior may be kept up by one or more light movable bridges, made of plank or boards, leading from the parapet across the ditch. These bridges should be kept inside the fort at night, or when an attack is anticipated.

"5. Every precaution should be taken to secure the magazines against vertical or curved fire. The entrance is the weak point; hence, where necessary, cover it by additional earth; put splinter-proof guards, made of timber or plank, around the door, and have water at hand, in barrels or casks, to extinguish any fire near the doorway; keep both doors shut, especially the inner one, allowing only one or two men to be inside, and only the ordnance sergeant, with an assistant, on the stairway to pass out the ammunition that may be called for. Keep all the ventilators closed, and fill, as far as practicable, all ventilating tubes with earth both outside and inside of the magazines.

"See that an ample supply of wads is kept on hand outside of the magazines, and that the ordnance sergeant makes careful report of the ammunition expended, and that it is promptly replaced.

"Fill at once any holes made in the magazine cover. Logs, fascines, or even sticks, laid against its exposed side, greatly reduce the penetration of shot, particularly of elongated projectiles, by deflecting them.

"6. Build merlons between barbette guns, and partially fill wide embrasures, as soon as the positions of the enemy's batteries and the proper direction of fire of each gun are ascertained. Cut away the foot of scarps to render escalade more difficult, taking care not to endanger the stability of the parapet. Use the earth so obtained for making a glacis and traverses across the abatis, if it be threatened by an enfilading fire. A few piles of earth across the abatis, particularly if the earth be wet, is a great security against such fire.

"Commanding officers of the forts cannot be too strongly impressed with the fact that the abatis is one of the main sources of strength to a field work. It should be carefully protected from injury and depredation, fire, etc.

"7. Bury percussion shells or hand grenades, to act as torpedoes, in the bottom of the ditch and outside of the abatis.

"8. Put up traverses on all faces liable to be enfiladed, to protect the guns, even if to obtain room for them some of the guns have to be removed; repair all damages to the parapet on the following night, if not practicable to do it before.

"Earth may be obtained for the above uses by excavating in the terre-plein for bomb-proof shelters, and by digging pits or holes, about three feet wide and deep, where ricochet shells are most likely to fall, and where the excavations will not seriously interfere with the defence; remove all sheds and wooden buildings lest they take fire.

"9. Construct temporary banquettes on all bomb-proofs and magazines, to afford an infantry fire on the probable front or points of attack. These may be made with plank resting on trestles or posts, or by cutting away the earth so as to afford standing room for infantry, with a parapet in front.

"10. When, or before, the enemy's approaches have been advanced to the vicinity of the work, a surprise, or sudden assault upon one or more of the forts, especially by night, may be anticipated. Under such circumstances it is the duty of the commanding officer, though he may have resorted to every expedient to retard the siege, to impress upon the garrison that they cannot, without loss of honor, either abandon the fort or surrender it without resisting at least one assault. Such is the inexorable law of war, and it should not be forgotten that it holds good whether or not there are other works in the rear to which the garrison might retire with comparative safety. When the attack is about to be made, the commanding officer of a fort should endeavor to inspire his men with confidence in their powers of resistance, with self-reliance and enthusiasm.

"Every preparation should be made to resist the passage of the ditch, by the fire of artillery and infantry, by torpedoes, by loaded shell and hand-grenades, and by attacking the enemy on the parapet.

"The commanding officer must decide beforehand, according to the particular circumstances under which he is called upon to act, how this attack should be made. If there be, behind bomb-proofs and magazines, banquettes and breast-heights for infantry bearing on the points of attack, then, at the proper moment, the field-pieces and howitzers should be withdrawn from the platforms, loaded with double charges of canister, and placed in positions where they may still be used against the enemy as he appears on the crest of the parapet or descends to the terre-plein; while the infantry should line these interior parapets and aid, by their fire, in driving the enemy from the work, the reserve charging furiously with the bayonet on the appearance of any confusion or disorder.

"If there be no such interior lines of infantry fire on the point of attack, then the enemy must be met with the bayonet on the top of the parapet. For this purpose one or more steps, made of boards, should be prepared beforehand, to enable the infantry to mount the parapet, and it should be impressed on the defenders that the assaulting troops, arrived at position, will be greatly fatigued, and necessarily in disorder, and, moreover, will be cut off from all external support, and hence that it is an opportune moment, by a vigorous assault with the bayonet, to hurl the enemy into the ditch, and to retrieve, with disaster to the foe, the endangered possession of the work and of the defensive line on which the safety of the nation depends.

"The firing of the guns, particularly howitzer and field-pieces, loaded with canister, should be continued as long as possible in order to delay the advance of the supporting columns; and, if the assault fail and the support be driven back in disorder, a sortie in force may be made and the enemy pursued into his works.

"Such sorties, however, should not be attempted by the troops in any particular fort, but should be made, under the direction of the commanding general, by the outside reserves, supported by the fire of all the forts and batteries bearing on the position to be taken."

The defences of Washington consisted of a chain of detached field-works of a stronger profile than is ordinarily used. Still, from their character, the capture by assault might be successful, and hence greater stress has been placed in the memoranda upon the course to be pursued during the assault. The general precautions to be taken, and recommendations given, in these memoranda, apply to the defence of works constructed upon a larger scale.

65. Three Periods of the Defence.—Like the attack, it is usual to divide the defence into **three periods**, corresponding to those given for the attack.

The first period includes the time from the first signs of a hostile movement up to the time that the investment is made complete and the preparations are made to begin work upon the trenches.

The second period corresponds exactly with that of the attack, which includes the time from the opening of the trenches until the completion of the third parallel.

The third period includes the time from the completion of the third parallel until the place is surrendered, or the siege is raised.

66. Steps Taken during the First Period.—In addition to the preliminary measures mentioned in Art. 64, thé commanding officer of the fortification makes a special arrangement of his troops to meet the emergencies which will now be constantly arising.

He sends cavalry patrols for several miles along the approaches leading to the place, to watch the movements of the enemy, and provides other means for collecting information.

All grain, cattle, provisions, and supplies, in the vicinity, are brought within the lines, and everything useful to the besiegers, in the neighborhood, is removed or destroyed.

If he has force enough to make an active defence, he will post troops upon the lines of the enemy's approach, at those points where a good defensive position can be obtained, and annoy and hinder as much as possible the besiegers' advance. He will be able to find out by these means the probable strength and the directions of the different bodies moving to invest the place, and may, by quick movements, be able to concentrate a larger force upon one or more of them, and thus defeat them.

Supposing himself pushed back to the works, or required to make a passive defence, his measures will be of a character to guard against surprise, and to hinder the besiegers in their labors on the trenches.

He divides the main body of his infantry into three grand reliefs, one to be **on duty**, a second to be **in support**, and a third, **at rest**. The main reserve is not included in this division, but is kept in hand to reinforce any portion of the work, whenever an emergency arises. The main reserve also furnishes the guards for the interior of the main work.

The gunners are divided into two reliefs, so arranged as to have half of the guns mounted ready to fire at a moment's notice.

Sentries are placed at the posterns, upon the parapets, and at those points which require particular watching. A guard, placed within the re-entering place of arms, furnishes sentries for the covered way and patrols for the glacis.

67. Returning the Fire of the Batteries of the First Position.—The besieged, having attempted to hinder the progress of the besiegers' work upon their preliminary batteries and the occupation of the ground in their front, but having failed, do everything in their power to have the batteries of the defences ready to reply to those of the besiegers, as soon as the latter open their fire. Knowing the ground thoroughly, the besieged should be able to open an effective fire upon the enemy's batteries when their positions are known.

As soon as the positions of the besiegers' batteries become known, the defence should concentrate their fire upon those batteries offering the best mark, and, after silencing them, should turn their fire upon others.

If, however, the besiegers have rightly prepared their batteries, their fire will be superior to that of the defence, and will, after a time, show this to be the case.

The besieged will then be obliged to withdraw their guns under shelter behind traverses, or into places prepared for them where they will be protected, so that they may be fit for use at a later period of the attack.

Traverses must be repaired, and should be strengthened, if necessary, and embrasures made in the parapets for the new directions which the guns may be required to have.

68. Steps Taken by the Defence during the Second Period.—The result of this preliminary artillery fire will without doubt convince the defence as to which will be the point of attack selected by the besiegers.

If no retrenchments are already existing upon this front of attack, the defence will take measures at this time to construct temporary ones. The kind of retrenchment will depend upon the nature of the case, as described in permanent fortifications. It is advisable, in their construction, to take all steps which will lighten the labors of those required to build them.

Counter attacks, and an increase in the number of the troops guarding the parts most liable to attack, are the principal steps to be taken during this period.

Counter attacks are of two kinds, those known as sorties, and those termed counter-approaches.

69. Sorties.—Sorties are of two kinds, **sorties in force,** and **small sorties.**

Where the garrisons are very strong, or can be easily reinforced, sorties in force may be used.

They are most effective, and most apt to be successful, about the time the second parallel is begun, as the guards of the first parallel are not then so near at hand to protect the working parties, as in the previous positions of the besiegers.

In a sortie of this kind, a force composed of all arms of service, as large as can be spared from the garrison, should be employed. A demonstration should be made upon one flank of the second parallel, whilst the main attack is directed upon the other. If successful, working parties are immediately thrown into the trenches, removing or destroying all tools, trench materials, etc., left behind by the besiegers, and levelling the parapets, filling the trenches, and burning all gabions, brush, and combustible materials found in the trenches.

The troops making the sortie retire as soon as there are evidences of a superior force moving against them.

Small sorties are not usually made until after the besiegers have advanced from the second parallel. These sorties have for their object to drive the sappers from their work, and to destroy the trench materials in the sap.

A force consisting of a company, or a platoon, or even a less number, will be sufficient, in many cases, for sorties of this kind. A light field gun is a useful adjunct of a sortie intended to destroy a sap. The gun can be quickly run upon the glacis, and into a position from which its fire can be brought upon the sap rollers used to protect the sappers. The sap rollers, displaced by this fire, leave the sappers exposed to a musketry fire, and force an abandonment of the sap.

70. Counter Approaches.—The method of counter approaches promises greater success, and is accompanied with less loss of life (an important factor of the defence, where the garrisons cannot afford large losses, and where they wish to reserve the troops for more favorable occasions of defence).

Counter approaches are similar in principle to the approaches made by the besiegers. They generally consist of trenches and rifle pits, and are constructed so as to have their interiors exposed to the fire from the defences in their rear.

The Russians made an effective use of this class of works in the siege of Sebastopol, in 1854.

71. Steps to be Taken during the Third Period.—The steps to be taken by the defence at this period of the attack are those having for their object to contest, and, if possible, to prevent, the crowning of the covered way, to delay the besiegers in their attempts to cross the ditches, and, finally to defend the breaches as long as possible.

The most effective means which can be used to delay the besiegers in their operations of crowning the covered way are those furnished by a good system of countermines. A resistance of this kind can be overcome by mining alone, and makes the progress of the besiegers a slow and costly one.

If mines are not used, the methods already described to delay the saps are employed.

The besiegers, having been successful in reaching the covered way, begin work immediately upon the galleries of descent, and upon the breaching batteries. It will be the object of the defence to bring a strong concentrated fire upon those points where the besiegers are at work, and by this fire, to delay, if not prevent, the galleries and batteries from being constructed.

In the passage of the ditch, the same efforts will be made to delay, if not prevent, the crossing. If the ditch is dry, sorties may be made to drive off the sappers, and to destroy the saps. These, in connection with strong fires to sweep the ditch, make the progress across it difficult, if not impossible.

When the ditch is a wet one, the difficulty of forcing a passage may be greatly increased, if arrangements have been made by means of which the levels of the water in the ditches can be quickly changed. The currents formed by the changes of level may be utilized to sweep away the dams or bridges which the besiegers may be constructing. The besiegers being successful in this operation, there remains only the breach to be occupied, and the besiegers are within the defences.

72. Defence of a Breach.—A breach is only a defile, and the object of the besieged is to make it an impassable one. With this object in view, the rubbish forming the slope may be removed during the darkness, thus rendering the slope too steep to be used by an assaulting column. The breach may be filled with shells, torpedoes, and other devices which would explode when stepped upon. Obstacles may be placed in it to delay the assaulting column under a close fire sweeping it. These methods would be attempted in case of an assault. If the besiegers, however, proceed by sap, and keep control of the breach by a fire from the lodgments on the covered way, the defence will make arrangements to prevent them from spreading out, after they have reached its summit. This may be done by arranging the traverses next to the breach so as to bring a fire upon it, and by constructing a temporary retrenchment, if there is no permanent one, which will bring a concentrated fire upon the breach.

It is safe to say that a breach, strewn with obstacles such as those described, and carefully guarded by an active defence, cannot be carried by any storming column, however strong it may be. It would only be possible when the besieged are in an exhausted condition, and utterly dispirited by their failure to keep the attacking forces back.

If there are strong interior retrenchments, it may be the best policy to leave the breaches undefended and retire within the retrenchments. Loss of life and further exhaustion of the troops will be avoided by this course.

73. Character of the Commander.—A defence is largely dependent upon the character of the commanding officer who has charge of it. An officer fit for such a command should possess good judgment, be full of energy, quick to act, and have a thorough knowledge of his profession. In all the cases of remarkable defences, it has been found that the commanding officers possessed exceptional qualities, and to these qualities were due the prolonged resistances offered.

Before the days of rifled arms, it was an inexorable law of war that no surrender of a fortified place should take place until at least one assault had been made. This law has not been so closely applied during the last sieges of which we have a record, but still it is considered to be in force.

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CHAPTER V.

METHOD OF DETERMINING THE COMPARATIVE STRENGTH OF ANY TWO FORTIFICATIONS.

74. Defensive Value of a Fortification.—The resistance which a fortified place is expected to offer to a systematic attack, depends upon the faithfulness with which the general principles of the art of fortification have been applied to the work during its construction.

To determine the comparative strength of any two systems, or methods of fortification, a careful analysis of the different parts of the works considered should be made, and the weak points in each noted. From the data thus obtained, a fair conclusion may be drawn as to their relative strength, all other things being considered equal.

After Vauban had laid down his general rules applicable to the systematic attack, Cormontaigne and his successors made use of these rules to devise a plan which might be used for comparing any two fortifications with each other.

Their method of comparison consisted in making upon paper a systematic attack upon each of the works considered, and in estimating the time it would take the besiegers, from the time the trenches were opened, to enter the main work by breaching its scarp. The one which required the greater length of time was considered the stronger.

The rate of the progress, on paper, of the siege operations supposed to be carried on, was obtained from the records of actual sieges, and from actual experiments.

This method of comparison is known as the "**fictitious siege.**" It has been called the "imaginary attack," and also, the "analysis of fortified places."

75. Journal of Attack.—Engineer officers, when on duty in the trenches, make notes of the daily amount of work done, the methods used, the time taken, etc., and of such other things as may be valuable for future reference. These notes are daily transmitted to the senior engineer officer on duty with the besieging forces, and are by him filed away, after the progress of the day has been entered on the journals and marked upon the plans. Sometimes models of the ground and the fortifications are made, and the progress of the siege marked upon these models.

The engineers on duty in the defence of a work are supposed to keep a journal of the defence.

The method of the "fictitious siege" is ordinarily illustrated by a supposed journal of attack, and of defence.

All new work in a systematic attack is generally begun just after dark, and engineers usually reckon the periods of twenty-four hours as nights, instead of days, having the night to begin with dusk.

The journal here given is supposed to be a record of the operations and progress during the siege, where the place attacked is fortified upon the bastioned system, by Cormontaigne's method, and at a period previous to the use of the modern arms of precision.

The point of attack selected by the besiegers is bastion **III**, in Fig. 16. The portion of the fortification included between the capitals of the demi-lunes adjacent to bastion **III**, forms the "front of attack."

The investment being complete, and the preparations for the siege being made, it is supposed that ground is broken for the first parallel, at a distance of 600 yards from the salients of the covered ways of the front of attack.

According to Vauban's rules there should be not less than three parallels, and as many approaches as can be conveniently made and used. In this case, there are supposed to be at least three of these approaches, which are directed along the capital of the bastion of attack and the capitals of its adjacent demi-lunes. These approaches are made to run in zigzag directions, so as not to be subjected to enfilading fire. It is considered advisable to limit the length of the largest branch to one hundred yards.

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1st Night.—*Attack.* The first parallel was begun immediately after dark, and was connected with the depots in rear by trenches. At daylight, the troops, who during the night were posted in front of the parallel to protect the working parties from sorties which the besieged might make, were drawn back into the parallel, and, with the tools left by the working parties, finished the parallel.

Defence. As soon as the besiegers were discovered to be at work, the guns bearing upon their position opened fire. Shells and fireballs were thrown from mortars to annoy their workmen, and to light up the positions occupied by them. Arrangements were begun to mount additional guns upon the front exposed to the attack, and to strengthen the salients of this front. Mortars were mounted in the salient places of arms, and field guns placed in the re-entering places of arms.

2d Night.—*Attack.* The ends of the parallel were extended during the night, to meet the prolongations of the façes of the collateral demi-lunes which brought a fire upon the field of attack. Field works, planned to bring a strong fire upon the flanks of the front of attack, were begun at each end of the parallel. Batteries to enfilade the faces of the demi-lunes and the bastion of attack, were begun, as well as batteries for curved fire.

The approaches leading from the first parallel, in the directions of the capitals of the work attacked, were begun and carried forward about 150 yards.

Defence. The additional guns making the armament complete for the front of attack were mounted. The mortar and barbette batteries kept up a strong fire upon the positions occupied by the besiegers' working parties. Small sorties were made to interrupt the labors of the besiegers. At daylight, all the guns in position opened fire upon the besiegers' works.

3d Night.—*Attack.* The construction of the batteries of the first parallel was continued, and the batteries armed by daylight. The approaches were pushed one hundred yards further toward the enemy's works.

Defence. During this night, a ricochet fire, in the direction of the besiegers' approaches, was kept up, and a concentrated fire brought upon those points where the besiegers appeared to be at work upon batteries. The traverses which were necessary to protect the terre-pleins exposed to enfilade fire were finished. Interior retrenchments in the demi-lune redoubts of the front of attack, and in the bastion of attack, were begun. At daylight, all the guns in position on the front of attack renewed their fire.

4th Night.—*Attack.* The fire of the defences being kept under, the second parallel was laid out, the work of its construction begun, and a considerable portion of it finished.

Defence. As soon as it appeared that the besiegers were at work upon the second parallel, a strong fire of canister and of musketry was brought to bear upon them.

5th Night.—*Attack.* The construction of the second parallel was resumed, and the parallel completed. The construction of counter-batteries was begun. A battery of eight guns against each face of the bastion of attack, a battery of six guns against the faces of the collateral bastions, a battery of six guns against the faces of the adjacent demi-lunes, and a battery of four guns against the faces of the collateral demilunes, were laid out.

Defence. A strong musketry fire from the covered way, and a fire of canister, were used to delay the progress of the working parties of the besiegers. Just before daybreak sorties were made to drive these parties from their work. Work upon the retrenchments was continued.

6th Night.—*Attack.* The construction of the counter-batteries was continued. Saps were broken out of the second parallel, and the approaches pushed forward for nearly one hundred yards further.

Defence. The defence consisted chiefly of ricochet fire along the capitals, and of musketry fire from the covered ways. Sorties were attempted, and the work on interior retrenchments, traverses, etc., continued.

7th Night.—*Attack.* The approaches were pushed forward fifty yards further, and demi-parallels (Fig. 17) constructed. In the extremities of the demi-parallels, howitzer and mortar batteries to fire into the covered ways were begun.

Defence. The defence pursued a similar course to that of the preceding night.

8th Night.—*Attack.* The howitzer and mortar batteries in the demi-parallels were finished, and armed, ready to begin firing at daylight. Saps were broken through the demi-parallels, and the approaches resumed. Loop-holes for musketry fire were made along the parapets of the parallels.

Defence. The defence employed sorties, and tried, by a strong fire of musketry and case shot, to keep the working parties and saps from making progress. Fire was constantly directed upon the heads of the saps whenever they could be seen.

9th Night.—*Attack.* The saps were pushed forward until they reached the foot of the glacis, about sixty yards from the crest of the covered way of the salient place of arms, and then prolonged a short distance to the right and left, in the direction of the third parallel.

Defence. The same means were used as on the previous night. Field pieces were used to destroy the sap-rollers, whenever they could be seen.

10th Night.—*Attack.* The third parallel was completed. This parallel, interfering with the enfilading batteries in rear, was arranged for batteries with curved fire, having the same object as the enfilading batteries. The batteries were armed, and were ready to begin firing at daylight.

Defence. The same means were used in the defence as on the previous night. Every exertion was made to hinder progress in the execution of the third parallel, and to drive the sappers from their labors.

11th Night.—*Attack.* Saps were broken out of the third parallel, and these were joined, forming the circular places of arms, **C**, **C** (Fig. 17). Saps intermediate to these were pushed forward, leading toward the re-entering places of arms. The unfinished batteries of last night were completed this night.

Defence. The whole object of the defence was to concentrate all the fire they could bring, both day and night, upon the heads of the saps.

12th Night.—*Attack.* Trench cavaliers, to sweep the covered way of the salient places of arms, were begun, and some progress made on the saps leading toward the re-entering places of arms.

Defence. Every effort was made to prevent work upon the trench cavaliers.

13th Night.—*Attack.* The trench cavaliers in front of the demi-lune covered ways were finished, and the saps pushed forward for a few yards.

Defence. Continued opposition was made to the construction of the trench cavaliers, and strong fires were brought to bear upon the ground which the besiegers were to occupy in crowning the covered way.

14th Night.—*Attack.* The crowning of the covered way, as far as the first traverses on the covered way, was completed, and the batteries on the glacis of the salient places of arms were begun.

Defence. Sorties and concentrated fires were used to retard the saps.

15th Night.—*Attack.* The construction of the batteries, begun on the previous night, was continued, and a descent into the covered way (Fig. 18) begun. The saps leading to the bastion covered way, and to the re-entering places of arms, were joined, as shown in Fig. 17.

Defence. The defence was of the same character as that of the previous night.

16th Night.—*Attack.* The batteries on the glacis of the demi-lune covered way were completed and armed. A gallery of descent into the ditch, passing under the first traverse, and then behind the counterscarp wall, was begun (Fig. 18). As soon as it was daylight the batteries opened their fire.

Defence. The defence was similar in character to that of the night before.

17th Night.—*Attack.* Fire from the batteries on the glacis was kept up, and the work upon the gallery of descent was continued.

Defence. Embrasures were cut, and guns mounted, in the curtain, near its extremities, to bring a fire upon the breach in the demi-lune.

18th Night.—*Attack.* The breaches in the demi-lune salients were made practicable, the passages of the demi-lune ditches were effected, and the crowning of the breaches by sap was completed. The lodgments on each side of the covered way were prolonged, and the construction of batteries for mortars and howitzers, for the purpose of reducing the demi-lune redoubts, begun. Those batteries used in breaching the demi-lunes which were available for the purpose, were directed upon the bastion of attack. Mines were begun in the salients of each of the demi-lunes, to blow up the salients of the demi-lunes, and expose the salients of their redoubts to the batteries on the covered ways.

Defence. Every effort was made, by fire from the demi-lune redoubts, and from the demi-lune cuts, to prevent the crowning of the breaches in the demi-lunes. Efforts were constantly directed to delay the saps.

19th Night.—*Attack.* The batteries in the prolongation of the lodgment of the covered way were completed and armed. The saps upon the glacis of the re-entering places of arms were pushed forward, and these places were crowned. Work was continued upon the mines in the demi-lunes. The breaching batteries kept up their fire upon the bastion.

Defence. The defence kept up a fire upon the heads of the saps, and attempted to prevent the crowning of the places of arms.

20th Night.—*Attack.* The mines in the demi-lune salients were finished and charged. A sap was broken out of the passage in the ditch of the demi-lune, and pushed forward to the length of one branch. The crowning of the re-entering places of arms was completed, and counter-batteries in these places were begun. At daylight, the mines in the demi-lunes were fired, and the batteries on the covered way opened fire, through the breaches made by the explosions, upon the redoubts.

Defence. The same measures of defence were used this night as for the one previous.

21st Night.—*Attack.* The batteries kept up their fire upon the bastion, and upon the redoubts in the demi-lunes. Sappers cleared a way through the breach in the demi-lune, and ran a sap across the ditch of the demi-lune redoubt. Work upon the counter-batteries on the glacis of the re-entering places of arms, was continued.

Defence. Active preparations were made to repulse any assault of the breach in the demi-lune redoubt. Fire was kept up on the heads of saps as before.

22d Night.—*Attack.* The saps along the ditches of the demi-lunes, toward the breaches in the bastion, were pushed forward. The ditch of the demi-lune redoubt was crossed, and a lodgment was made in the salient of the redoubt. Two saps were pushed along the faces of the redoubt toward the retrenchment which had been thrown up during the siege. The occupation of these zigzags along the faces of the redoubt rendered the demi-lune cuts untenable. Zigzags were run along the parapets of the demi-lunes, until the interiors of the redoubts of the re-entering places of arms were seen. The occupation of these trenches forced the besieged to retire from these works. The counter-batteries of the re-entering places of arms were finished, and descents, from the lodgments on the demi-lune glacis, into the covered way, were made.

Defence. A strong defence was made against the lodgment in the breaches of the demi-lune redoubts, but was unsuccessful. The defence of the cuts was continued until it was no longer possible to hold them.

23d Night.—*Attack.* The saps along the faces of the demi-lune redoubts were connected by trenches across the redoubts, parallel to the retrenchments of the besieged. As soon as completed, an attack was made upon the retrenchments, and was successful in driving the besieged out of them. The saps were then pushed forward in the ditches of the demi-lunes, until the main ditch was reached.

Defence. The attack of the besiegers upon the retrenchments of the demi-lune redoubts was made a bloody one, but could not be repulsed. The men in the retrenchments were withdrawn through the double caponnières, and back into the main work. Fire from the enceinte curtains was opened upon the interior of the demi-lune redoubts.

24th Night.—*Attack.* The firing from the breaching and counter-batteries was steadily kept up. The construction of batteries was begun in the demi-lune redoubts, and the batteries were ready to fire at daylight. Saps were run across the main ditch, to the foot of the breaches in the bastion.

Defence. Every preparation was made to defend the breaches in the bastion, and arrangements were made to retire within the interior works, if the besiegers should be successful.

25th Night.—*Attack.* With the aid of the fire of the batteries in the demi-lune redoubts, the workmen were able to so reduce the slopes of the breaches as to render them practicable for assault.

A practicable breach being made in the main work, the fictitious siege is here terminated. The movements beyond this point would be dependent upon the kind of interior works, and upon the strength of the defence.

76. Value of the Method of Fictitious Siege.—This method certainly furnishes a means of comparison in a general sense between two given works, but does not give a practical test of the strength of any single work.

No method of calculation can determine beforehand how long a fortified place will hold out against a systematic siege. The resistance that a fortification may offer is dependent upon too many things beside the height of its scarps and thickness of its parapets for any calculation to be accurate.

In using the method of the fictitious siege, engineers have generally taken ten days for the period from the opening of the trenches to the completion of the third parallel.

Although this period is safe enough for the purpose of comparison of two works, it would hardly do for determining the period of resistance of a single work.

The French and Spaniards, in the siege of Gibraltar, did not, in three years, get within 800 yards of the fortifications; and the French and English, at Sebastopol, were eleven months in getting near enough to render an assault practicable.

PART III.

MILITARY MINING.

CHAPTER I.

NOMENCLATURE AND THEORY OF MINES.

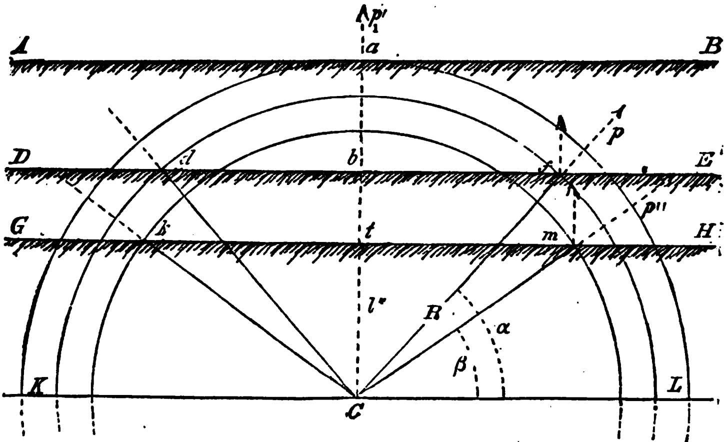
1. Nomenclature.—The object of military mining is to provide means for destroying, or rendering useless, works constructed by an enemy, or works abandoned by ourselves, and for making unsafe the ground over which an attacking enemy must pass. The means employed are explosive compounds, placed beneath the surface of the ground, or under the structure to be destroyed, and fired at the proper time.

The excavation in which the explosive compound is placed, is called the **chamber**; the hole produced by the explosion, is termed the **crater**; the passages by which the miner reaches the chamber are, when vertical, called **shafts**; and when horizontal, or slightly inclined, are known as **galleries**. The whole construction is termed **a mine**.

2. Theory of Explosion and its Effect.—Suppose a chamber to have been excavated, filled with an explosive compound, and all passages leading to it carefully stopped. If this explosive substance, now known as the **charge**, is ignited, there is at once formed a large volume of gaseous products. These gases tend to occupy a much larger space than that furnished by the chamber which held the charge. The effect of the expansion of the gases thus confined is to produce a strong pressure upon the sides of the chamber, and if the limit of rupture be passed, to blow out the side, or sides, offering the least resistance to the pressure.

If the limit of rupture, or better, if the limit of elasticity, be not passed, the pressure will be converted into a series of oscillations of the gases and of the particles forming the sides of the chamber, such that the effect produced by the sudden conversion of the compound into a gaseous state may be compared to that produced by a series of blows, given with great force and great rapidity, to the sides of the chamber.

Fig. 1.



$Ca = R_{,} \quad Cb = l \quad Cf = R.$

If the limit of elasticity is not passed, all the particles return to a state of rest, and no change of form in the chamber is noted.

If this limit is passed, but the limit of rupture of the material forming the exterior surface be not passed, it will be found that an enlargement of the chamber has followed, and that the ground near this chamber has been compressed into a condition more compact than usual.

If the limit of rupture is passed, it will be followed by the blowing out of one of the sides, and the formation of a crater.

The question to be primarily considered is the one in which a crater is formed.

3. Formation and Form of Crater.—Suppose a charge to be concentrated at a point, as **C** (Fig. 1), in a mass of homogeneous material too strong to have its limit of rupture passed by the effect produced when the charge is ignited, and suppose the charge to be fired.

The pressure exerted by the gases is supposed to act radially in all directions, and from the centre of the charge.

Since, by hypothesis, the material inclosing the charge is homogeneous, the surface of uniform pressure will be that of a sphere, having its centre at the centre of the charge; and the pressures upon a unit of surface of two spheres of this kind will vary inversely with the surfaces of the spheres.

Represent the pressure upon the unit of surface of the sphere whose radius is **R**, by p, and, of **R**$_{,}$, by p'. Then we have

$$p : p' :: 4\pi R_{,}^2 : 4\pi R^2,$$

or

$$p : p' :: R_{,}^2 : R^2.$$

That is, *the intensities of pressure, upon units of surface at different distances from the centre of the charge, are to each other inversely as the squares of their distances.*

Suppose the distance **C** a (Fig. 1) to be such that the effect of the explosion is just sufficient to disturb the position of the particle, a, but not that of any other particle on the surface, **AB**. The explosion would produce no crater.

If the charge be increased, or the same charge be brought nearer to the surface, **AB**, than before, and then ignited, the effect will be to violently displace a number of the particles lying above the charge, and to throw some of them beyond the surface, **AB**, thus forming a crater.

The form of the crater has been a subject of discussion among military engineers for many years, and has been assumed by them to have various shapes.

Vauban assumed the form of the crater, when its volume was the greatest, to be that of a right cone, whose vertex was at the centre of the charge, and whose elements, cut out by a meridian plane, were at right angles with each other.

This form of crater has been adopted by many military engineers, and has been proved by recent experiments to be very nearly correct.

A cone, with its vertex at the centre of the charge, is the form assumed for the crater in this discussion.

4. Maximum Crater.—The term maximum crater is used to designate that crater whose volume is a maximum for the same charge and for the same material.

If a charge be placed at **C** (Fig. 1) resting upon a free surface as **KL**, and fired, there will be no crater; if a charge equal in amount be at **C**, and the free surface be **AB**, at a distance such that no disturbance shall result from the firing of the charge, excepting the slight displacement of the single particle at a, there will be no crater. If the free surface be intermediate to these, like that of **DE**, or **GH**, there will be a crater produced whenever a charge equal in amount is exploded at **C**. The problem is, to find that crater which for this charge furnishes the maximum volume.

Suppose a charge placed at **C** (Fig. 1) and the cone d **C** f to be the crater formed by its explosion. Represent the depth, b**C**, of the crater by l, and the radius of the upper surface, called the **crater radius**, by r.

The volume of the cone will be as follows:

$$V = \tfrac{1}{3} \pi l r^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Denote the angle f **CL** by α. From the triangle $f\ b$ **C** we have,

$$r = \frac{l}{\tan \alpha},$$

which being substituted for r in *eq.* (1) gives

$$V = \tfrac{1}{3}\pi \frac{l^3}{\tan^2 \alpha}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Suppose this charge at C, which produced the crater d C f when exploded, to have the effect of only disturbing the single particle at a, when the charge is fired at the distance a C from the free surface. Represent the pressure upon the unit of surface (produced by the radial force) at the particle f by p, and that upon the unit of surface at a by p'.

The intensity of the force p must be greater than that of p', because it is much nearer the centre of disturbance. The conditions of disturbance for the two particles at f and at a are the same. They are slightly displaced, and the displacement does not extend to the particle next to them upon the right. It therefore follows that the vertical forces acting at these points a and f to displace these particles must be equal in intensity.

The vertical force acting upon a unit of surface at a, is p', and that at f, is $p \sin \alpha$; hence, $p' = p \sin \alpha$.

It has been assumed that the radial forces are to each other inversely as the squares of their distances from the centre of disturbance; hence

$$p : p' :: R_{\prime}^2 : R^2,$$

or

$$p : p \sin \alpha :: R_{\prime}^2 : R^2;$$

whence

$$\sin \alpha = \frac{R^2}{R_{\prime}^2}, \text{ and } R = R_{\prime}\sqrt{\sin \alpha}. \quad . \quad . \quad . \quad . \quad (3)$$

In triangle $f b$ C, we have

$$l = R \sin \alpha,$$

and giving to *R* its value in *eq.* (3) we get

$$l = R_{,} \sqrt{\sin^3 \alpha}.$$

Substituting this value of *l* in *eq.* (2) we have

$$\text{V} = \tfrac{1}{3} \pi \frac{R_{,}^3 (\sin^3 \alpha)^{\frac{3}{2}}}{\tan^2 \alpha} = \tfrac{1}{3} \pi R_{,}^3 \frac{\sin^2 \alpha \sin^{\frac{5}{2}} \alpha}{\tan^2 \alpha},$$

and by reduction,

$$\text{V} = \tfrac{1}{3} \pi R_{,}^3 \cos^2 \alpha \sin^{\frac{5}{2}} \alpha. \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The factor $\frac{1}{3} \pi R_{,}^2$ is constant for equal charges and in the same material. Differentiating the rest of the expression with respect to α, and placing the first differential co-efficient equal to zero, we have

$$- 2 \sin^{\frac{5}{2}} \alpha \cos \alpha \sin \alpha + \frac{5}{2} \cos^2 \alpha \sin^{\frac{3}{2}} \alpha \cos \alpha = 0.$$

Reducing, we obtain

$$\frac{5}{2} \cos^2 \alpha = 2 \sin^2 \alpha,$$

and

$$\tan \alpha = \sqrt{\tfrac{5}{4}}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

The value of this tangent is 1.118, and corresponds to the angle 48° 11′ 23″.

Hence, if the angle which the sides of the cone make with the horizontal be 48° 11′ 23″, or the quotient which is obtained by dividing the line of least resistance, *l*, by the crater radius, *r*, be equal to 1.118, the volume of the crater is a maximum.

This quotient of $\frac{l}{r}$ differs but slightly from unity.

When the crater radius is equal to the line of least resistance, the volume of the crater is very nearly a maximum, and the corresponding mine is called a **common mine.** When the crater radius is greater than the line of resistance, the mine is called an **overcharged mine**; when less, an **undercharged mine.** When no exterior disturbance is produced, or no crater is formed, the mine is called a **camouflet.** The line drawn from the centre of the charge to the edge of the crater, or the right-line element of the cone, is called the **radius of explosion.**

5. **Determination of Value of $\mathbf{R}_{,}$.**—Under the hypothesis that the particle at a was the only one upon the free surface that was disturbed, it follows that this particular value of $R_{,}$ will be the limit beyond which there will be no crater.

To find this limit; from the maximum crater we find

$$\frac{l}{r} = 1.118,$$

and from the triangle $b\,C\,f$, $R^2 = l^2 + r^2$, in which, substituting for r its value, we have

$$R^2 = l^2 + \frac{l^2}{(1.118)^2},$$

whence

$$R^2 = 1.8\,l^2,$$

and

$$R = 1.3416\,l. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

From the triangle $b\,C\,f$, we have $\sin\alpha = \frac{l}{R}$, and from *eq.* (3), $\sin\ \alpha = \frac{R^2}{R_{,}^2}$. Equating these values of the $\sin\alpha$, we obtain

$$\frac{R^2}{R_{,}^2} = \frac{l}{R}; \text{ whence, } R_{,}^2 = \frac{R^3}{l}.$$

Substituting for $R_{,}$ in this expression the value given in *eq.* (6), there results

$$R_{,}^2 = (1.3416)^3\,l^2 = 2.415\,l^2,$$

whence,

$$R_{,} = 1.554\, l \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

That is, no crater will be formed whenever the centre of the charge is distant from the surface 1.554 times the length of the line of least resistance of the maximum cone for this charge.

6. Determination of the Length of the Side of any Crater.—Represent the crater radius of a cone as *h* C *m* (Fig. 1) by $r_{,,}$, the line of least resistance by $l_{,,}$, and the side of the crater by $R_{,,}$. If the crater exists, a measurement of the radius and of the depth can be made, even when the side is difficult to measure, and then substituting the values thus obtained in $R_{,,} = \sqrt{l_{,,}^2 + r_{,,}^2}$, and solving, the value of $R_{,,}$ can be found.

It has been found very useful for other purposes to find the length of the side in terms of the line of least resistance of the maximum cone.

The length is obtained as follows:

Since the conditions imposed upon the particles at *a*, and at *m*, are the same, we have from the method followed for *eq.* (1), calling β the angle which the side makes with the horizontal,

$$\sin \beta = \frac{R_{,,}^2}{R_{,}^2}.$$

Substituting in this value of $\sin \beta$, the value of $R_{,}$, from *eq.* (7), we have,

$$\sin \beta = \frac{R_{,,}^2}{(1.554)^2\, l^2},$$

from which we get,

$$R_{,,} = 1.554\, l \sqrt{\sin \beta}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

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From the triangle *t* C *m* (Fig. 1) we get

$$\sin \beta = \frac{l_{,,}}{R_{,,}}.$$

Equating this value of sin β, with its first value obtained, and solving, we get

$$R_{,} = \sqrt{\frac{R_{,,}^3}{l_{,,}}}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

That is, the limit of the radius of explosion to produce a crater is equal to the square root of the third power of the radius of explosion of the experimental mine divided by its line of least resistance.

Professor Höfer, of Germany, has formed a table, by means of *eq.* (8), which is very useful in mining calculations.

Assuming l to be unity, the table is formed by giving all values to α, from 0° to 90°. In this table, he writes opposite to each angle, the tangent; the difference between the tangents for the consecutive angles used; the length of the radius of explosion; the value of the cube of the ratio of the radii of explosion, $\left(\frac{R}{R_{,,}}\right)^3$; and the differences of these powers of R and $R_{,,}$.

Since it is not always easy to measure the angle β, but is comparatively easy to measure $l_{,,}$ and $r_{,,}$, he gives in his table the value of the tangent, from which the angle is easily found. Then, having an experimental crater, he makes $l = 1$ in the formula, and substitutes for the radical its value *eq.* (8). The resulting value for $R_{,,}$ will be the length of the **radius of explosion** in terms of the line of least resistance of the corresponding maximum crater, regarded as unity. The radius of explosion of the experimental crater is also obtained by measuring $l_{,,}$ and $r_{,,}$, and by solving $R_{,,} = \sqrt{l_{,,}^2 + r_{,,}^2}$. This value, divided by that of $R_{,,}$ obtained from the table, regarding the length of the line of least resistance as unity, will give the line of least resistance of the maximum cone, for the charge exploded in the experiment, in terms of the unit used to measure l'' and r''.

7. Relations Between the Lines of Least Resistance of Different Craters for the same Charge.—Suppose d C f to be the maximum crater for a given charge exploded at **C**, and k **C** m a crater formed by the explosion of a charge of equal amount, but at a less distance from the free surface. Represent the radial force upon the unit of surface at m by $p_{,,}$, the line of least resistance by $l_{,,}$, the radius of explosion by $R_{,,}$, and the angle m **CL** by β.

Since the conditions of equilibrium are the same for the particles at f and at m, the vertical components of the radial forces at these points are equal. The vertical component at f is given by the expression, $\frac{p\,l}{R}$, and that at m, by $\frac{p_{,,}\,l_{,,}}{R_{,,}}$.

Equating these expressions, we obtain

$$\frac{p\,l}{R} = \frac{p_{,,}\,l_{,,}}{R_{,,}},$$

whence,

$$\frac{p}{p_{,,}} = \frac{l_{,,}R}{lR_{,,}}.$$

By hypothesis,

$$\frac{p}{p_{,,}} = \frac{R_{,,}^2}{R^2},$$

hence,

$$\frac{R_{,,}^2}{R^2} = \frac{l_{,,}R}{lR_{,,}},$$

which may be placed under the form,

$$l : l_{,,} :: R^3 : R_{,,}^3,$$

whence,

$$l = l_{,,}\left(\frac{R}{R_{,,}}\right)^3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The proportion given above is true for any two craters, and shows that, with the same materials and equal charges, the lines of least resistance of the two craters formed are to each other as the cubes of the lengths of their sides.

The expression for the value of l, in *eq.* (10), shows that the line of least resistance of the maximum cone is equal to that of an experimental cone, multiplied by the cube of the ratio of the lengths of the sides of the experimental and maximum craters.

This expression affords a quick method of obtaining the line of least resistance of a maximum crater from a single experiment, and by the use of Professor Höfer's table.

A charge is exploded, and the depth of the crater, and its crater radius, are measured. The former divided by the latter gives the tangent of the angle which the side of the experimental crater makes with the horizontal.

Going to the table and finding the corresponding tangent, there will be found on the same line with it, under its proper heading, the value of the cube of the ratio of the sides. This, multiplied by the line of least resistance of the experimental crater, gives the corresponding line for the maximum crater for that charge.

8.—Determination of Maximum Crater Radius.—In military mining it is desirable to know how to determine, for a given line of least resistance, the crater which shall have the maximum crater radius.

Suppose the crater $k_{,}\mathrm{C}\,m$ to be one of this class, which has its base a maximum. Using the former notation, we have, from *eq.* (3)

$$R_{,,} = R\sqrt{\sin\beta}.$$

From the triangle $m\,\mathrm{C}\,t$, we have $R_{,,} = \frac{r_{,,}}{\cos\beta}$, which substituted for $R_{,,}$, gives

$$r_{,,} = R\cos\beta\sqrt{\sin\beta}.$$

For equal charges and the same material, R is constant. Differentiating the factor, $\cos\beta \sin^{\frac{1}{2}}\beta$ with respect to β, and placing the first differential co-efficient equal to zero, we have

$$-\sin^{\frac{1}{2}}\beta \sin\beta + \frac{1}{2}\cos\beta \sin^{-\frac{1}{2}}\beta \cos\beta = 0.$$

whence,

$$\frac{1}{2}\cos^2\beta = \sin^2\beta,$$

and

$$\tan\beta = \sqrt{\tfrac{1}{2}} = 0.7071. \quad . \quad . \quad . \quad . \quad . \quad (11)$$

which corresponds to the angle, 35° 15′ 30″.

That is, when the sides of the crater make an angle of 35° 15′ 30″ with the horizontal, the crater radius will be a maximum for the charge used.

If the line of least resistance be taken to be unity, then

$$r_{\prime\prime} = \frac{1}{0.7071} = 1.4142.$$

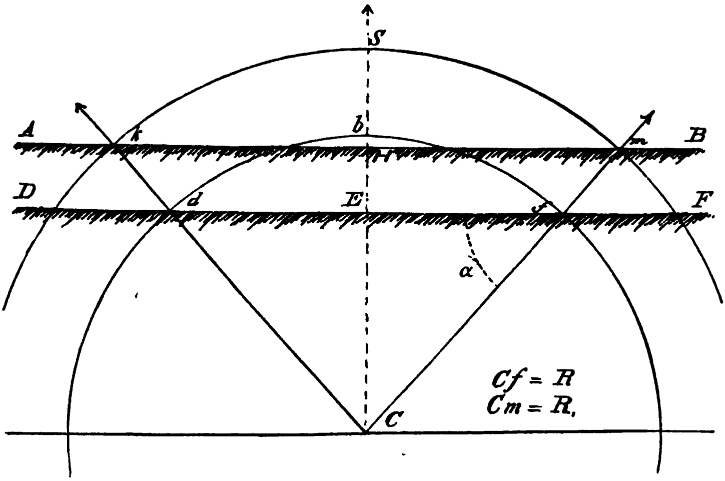
9. Determination of the Charge.—In the previous discussions, the charges have all been considered equal in amount. It is a matter of importance to be able to determine what the effect will be when there is employed a charge which is greater or less than the one which is known.

Suppose a charge to be placed at **C** (Fig. 2), and at such a distance below the free surface, **DF**, that a maximum crater is formed when the charge is exploded. The triangle d**C**f (Fig. 2) may be taken to represent the meridian section of the crater, and the line **EC**, its line of least resistance. Denote by p the radial pressure on the unit of surface, at the distance **C**f from the charge.

Now, suppose a charge of greater explosive power to be placed in the same material, and situated so as to produce a maximum crater when it is fired. The line of least resistance will be greater than before, because the charge is more powerful; that is, the charge must have been placed deeper in the material surrounding the chamber.

Suppose a meridian section of this second crater formed in this way to be placed upon that of the first, the centres of the charges and the lines of least resistance coinciding. The triangle *k* **C** *m* may be taken to represent the meridian section of the second crater, and the line **CH** its line of least resistance.

Fig. 2.



Represent the charge used in the first mine by C, and that used in the second mine by $C' = m\,C$, m being the number of times the charge of the second mine is greater or less than that of the first mine. The explosion of the second charge produces m times the effect of that produced by the first charge.

The material in which the mines have been made has been supposed to be the same for each, and the craters produced in each case were maximum craters. It follows, then, that the pressure on the unit of surface at f, due to the first charge, is exactly equal to the pressure on the unit of surface at m, due to the second charge. It also follows that the pressure upon a unit of surface at the distance Cf from the charge, produced by the charge C′, will be *mp*.

The sum of all the forces produced by the explosion of the second charge upon the spherical surface, *dbf*, will be equal in amount to the sum of all acting upon the spherical surface, *ksm*. Hence,

$$4\,\pi\,R^2\,mp = 4\,\pi\,R_{,}^2\,p,$$

or

$$R^2\,m = R_{,}^2.$$

But

$$R : R_{,} :: \mathrm{CE} : \mathrm{CH} :: l : l_{,}.$$

hence

$$l_{,}^2 = ml^2, \text{ and } l_{,} = l\sqrt{m} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Suppose a third mine of the same kind and in same material, made by firing the charge $C'' = nC$. By the same reasoning, we would find

$$l_{,,} = l\sqrt{n},$$

for its line of least resistance.

Comparing $l_{,,}$ with $l_{,}$, we have

$$l_{,} : l_{,,} :: \sqrt{m} : \sqrt{n},$$

or, the *lines of least resistance of mines of maximum craters are to each other as the square roots of the charges.*

The volume of the crater produced by the charge C, is

$$\tfrac{1}{3}\,\pi\,r^2\,l; \text{ and that produced by } C', \text{ is } \tfrac{1}{3}\,\pi\,r_{,}^2\,l_{,}.$$

Since $r : r_{,} :: l : l_{,}$, we obtain $r_{,}^2 = \frac{r^2\,l_{,}^2}{l^2}$; and representing the volumes of these craters by V and V′, we have, by substituting this value of $r_{,}^2$,

$$V = \tfrac{1}{3}\,\pi\,r^2\,l, \text{ and } V' = \tfrac{1}{3}\,\pi\,\frac{r^2\,l_{,}^2}{l^2}\,l_{,}.$$

Substituting for $l_{,}$ its value from *eq.* (12) we get

$$V' = \tfrac{1}{3}\,\pi\,r^2\,l\,m\,\sqrt{m}.$$

Comparing the values of V′ and V, we have

$$V : V' :: 1 : m\sqrt{m} \quad . \quad . \quad . \quad . \quad . \quad (13)$$

That is, the volumes of the craters increase in a more rapid proportion than the charges which produce them. For example, if the charge C′ had been four times as great as the charge C, the resulting volume of V′ would have been, not four times, but *eight* times that of V.

From *eq.* (12), we have $l_{\prime} = l\sqrt{m}$, whence $l_{\prime}^2 = l^2\, m$, or $m = \frac{l_{\prime}^2}{l^2}$. But C : C′ :: 1 : m, hence $m = \frac{C'}{C}$. Equating these values of m, we can write the proportion,

$$C : C' : : l^2 : l_{\prime}^2 . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

That is, *the charges producing maximum craters, in the same material, are to each other as the squares of their lines of least resistance.*

Since the sides of these craters are directly proportional to their lines of least resistance, this last proportion may be written.

$$C : C' : : R^2 : R_{\prime}^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Examining this proportion, it will be seen that the quotients obtained by dividing the charges used in these two mines by the squares of the radii of explosion, are equal. Hence, *the charge producing a maximum crater divided by the square of the radius of explosion, is always a constant quantity for the same material and for the same explosive.*

Represent this constant quantity by k, and we have

$$C' = kR_{\prime}^2 . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

Knowing the value of k and the length of $R_{\prime}$, the amount of the charge can be easily found. This constant k has been called the **charge co-efficient.** The determination of the values of the charge co-efficient forms a problem which is to be solved hereafter, by experiment.

Knowing k for different explosives, it will be easy to compare them with reference to their efficiency and cost.

10. Application of the Formulas.—Suppose a charge of 337 pounds of powder, when exploded, to have produced a common mine, with a crater radius of fifteen feet; what was the length of the radius of explosion; the length of the line of least resistance of the maximum crater for this charge; and the limit beyond which no crater would be formed?

By hypothesis,

$$r_{\prime\prime} = l_{\prime\prime} = 15';$$

and we find,

$$R_{\prime\prime} = 21'.2,\ l = 16'.25, \text{ and } R_{\prime} = \sqrt{635} = 25'.2.$$

That is, the charge, if placed one foot and a quarter lower down, would have produced a maximum crater; and if deeper than twenty-five feet, there would have been no crater formed.

11. Example.—Suppose it is desired, in the same material, and with the same kind of powder used in last case, to have had a mine six feet deep with a crater radius of twelve feet, what would have been the charge to use?

With $l_{\prime\prime} = 6'$ and $r_{\prime\prime} = 12'$, we would get $R_{\prime\prime} = 13'.4$. The value of $R_{\prime}$, by *eq.* (7), or (9), will be $\sqrt{401} = 20'$.

The charges are not proportional to the squares of the radii of explosion, because the cones are not similar; but they will be proportional to the squares of the values of $R_{\prime}$, the limit in each mine. Hence,

$$k = \frac{C}{R_{\prime}^2} = \frac{337}{635} = 0.53,$$

and

$$C' = 0.53 \times 401 = 212 \text{ pounds},$$

the required charge to be used.

CHAPTER II.

PRACTICAL CONSTRUCTION.

12. Linings of Shafts and Galleries.—Shafts and galleries belonging to a system of mines may be either of a **permanent** or of a **temporary** nature. When prepared in advance of any immediate necessity for their use, they are usually of a permanent class. Galleries of this kind are used in connection with the defence of permanent works, and are generally lined with some durable material, as masonry, to prevent the earth from caving in and filling the galleries. Galleries and shafts hurriedly constructed in the attack of a place, or in its defence, are usually temporary, and the linings for them are made of wood and timber obtained in the vicinity. It is the latter class that we particularly desire to notice.

13. Nomenclature.—The lining of a gallery, or a shaft, may be made of pieces of boards put together, forming what is known as a **case**; or it may be made of planks, supported at intervals by constructions called **frames.**

Whether the lining is made of cases, or of planks and frames, the pieces of which it is composed receive the same names. The piece which is to be laid upon the bottom of the gallery is called the **ground-sill**; the side pieces framed into the ground sills are known as **stanchions**; and the upper pieces resting upon the stanchions are called **cap-sills.** The planking used with the frames is called the **sheeting**; and the small strips which are frequently employed to keep a frame in its proper position until it can be securely fastened are termed **battens.**

14. Names of Galleries.—Galleries are of different dimensions, according to the objects to be attained by them, and are named from the dimensions given them. The names by which they are now most generally known are **great** or **grand galleries, principal, common,** and **branch galleries.** When the bottom of the gallery is not horizontal, it is termed an *ascending,* or a *descending* gallery, according to its inclination with the horizontal.

Great galleries are made large enough to allow the passage of cannon through them. For this purpose they are given an interior height of six feet and six inches, and a width of seven feet.

Principal galleries have the same height, but are only half as wide.

Common galleries are made four feet and a half high, and from three feet to three and a half feet wide.

Galleries having dimensions less than those named for the common galleries are termed branches.

Cases are made of planks two inches thick; sheeting is made of planks an inch, or one and a half inches thick; and frames are made of scantling, such as are found in buildings, or of pieces of timber cut and hewed into shape. The material used in these constructions may be either oak or pine, or other suitable wood.

15. Table of Dimensions.—The dimensions of the pieces of a frame depend upon the pressure they will have to support. The following table gives the dimensions which are considered safe under the ordinary circumstances of military mining, and when the frames in the gallery are placed not more than four feet apart.

TABLE.

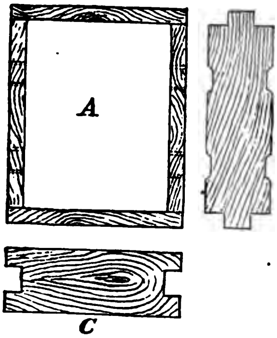
KIND OF GALLERY.	INTERIOR DIMENSIONS OF GALLERY.	CROSS SECTION OF SCANTLING.		
		GROUND-SILL.	STANCHION.	CAP-SILL.
Great gallery...	6½′ × 7′	6″ × 3″	6″ × 6″	6″ × 9″
Principal gallery	6½′ × 3½′	6″ × 3″	6″ × 6″	6″ × 8″
Common gallery	4½′ × 3½′	5″ × 3″	5″ × 5″	5″ × 6″
Branch gallery..	3½′ × 2½′	4″ × 3″	4″ × 4″	4″ × 5″

16. Shafts.—When the passage leading to a gallery, or a mine chamber, is vertical, it is called a **shaft**. The cross section of a shaft is usually made either square or rectangular, when the shaft leads to a gallery; if it leads only to a mine chamber at the bottom, and there is no danger of the sides caving in, it may be made with any cross section whatever.

When the object of a shaft is to furnish a passage to a point from which a gallery is to be made, or as it is technically termed, "to be driven," the interior dimensions of the shaft must be at least equal to the outside dimensions of the gallery frame, with its sheeting. That is, supposing a common gallery is to be driven from the bottom of a shaft, the side of the shaft from which the gallery starts must be of sufficient size to allow room for the gallery frame at the entrance to the gallery. If the interior width of this frame is to be three feet and a half, the stanchions to be five inches thick, and the sheeting one and one-half inches, the interior width of the shaft for the side from which the gallery starts should not be less than four feet and seven inches. It may be less when the gallery is only three feet wide. Shafts in loose soil must have the sides supported to prevent the earth from caving. This may be done either by using cases, or by using frames and sheeting.

17. Construction of Shaft, using Cases.—A **case** consists of four pieces of two-inch plank, one foot wide, and of the length required. The case when framed together is represented by **A**, in Fig. 3. The stanchion is shown at **B**, and the upper, or lower, piece at **C**.

Fig. 3.



In a shaft, the case occupies a horizontal position; in a gallery, a vertical one (Fig. 4).

It will be observed that tenons, two inches long and four inches wide, are cut in the ends of the stanchions, which are to fit into mortises of the same dimensions in the other two pieces. Notches are cut in the stanchions to facilitate handling when the pieces are being put in position, or being removed.

In sinking a shaft lined with cases, the first case is laid on the ground with its centre over the centre of the proposed shaft, and its longer sides parallel to the direction of the gallery which is to be driven from the bottom of the shaft.

The ground is then marked around the case, and all the earth within this space is removed for a depth of a little over one foot. The case is then inserted, so that its upper surface is level with the surface of the ground, and the earth then rammed around its sides to keep it firmly in place.

In placing the second case, the earth is excavated first for one of its ends, then for one of the sides, then for the other end, and lastly for the remaining side, the pieces being placed singly in position, and no more earth being excavated than is necessary, excepting for the last side. In the latter case, an excavation is made, as shown in Fig. 5, behind the proper position of the piece, into which space the end of the side can be pushed so as to have it beyond the end of the piece into which it is to be framed. It is then drawn forward into its place, with the tenon fitting into the mortise of the end piece. The earth in the middle of the case is then excavated as far as the bottom of the second case.

The third, fourth, and succeeding cases are placed in a similar manner, and the operation continued until the shaft has reached the required depth.

In good soils, the cases need not be placed so as to form a continuous lining, but may be placed at intervals of two, or even three, feet apart. In fact, in some particular instances they may be entirely omitted. But when the ground is loose, as it is ordinarily where it is "made" ground, a lining must be used.

Fig. 4.

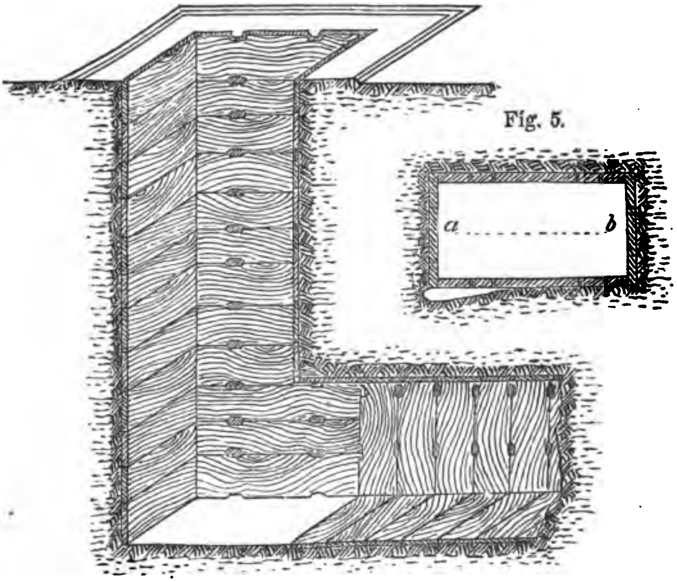


Fig. 5.

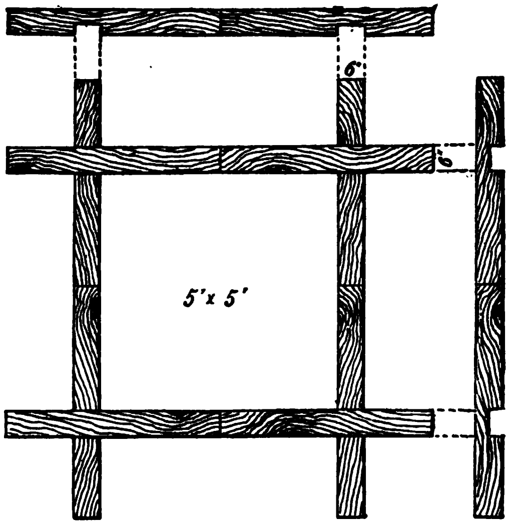
18. Construction of Shafts with Lining of Frames and Sheeting.

—The precaution, to keep the lining built as fast as the excavation proceeds, is to be taken where frames and sheeting are used the same as when cases were employed.

A shaft frame is composed of four pieces of scantling, halved into each other, forming a clear interior space within the frame of the size required for the shaft.

The first frame is placed in position upon the surface of the ground and receives the name of **top frame**. It differs from the others in having the ends of its pieces to project a foot or more beyond the sides (Fig. 6).

Fig. 6.

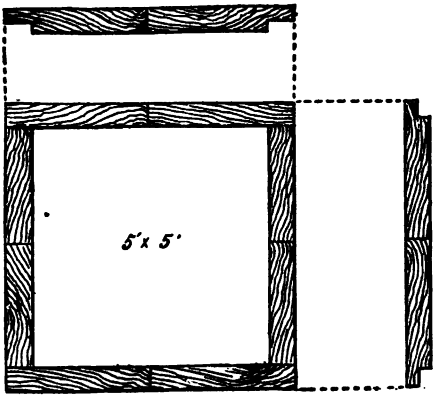


The remaining frames, known as **shaft frames**, have an interior space equal to the interior space of the shaft, the ends of the pieces being flush with the sides (Fig. 7).

The first thing to be done in the construction of a shaft is to determine the number of frames necessary to be employed. This number depends upon the depth of the shaft, and upon the kind of soil.

Knowing the depth the shaft is to have, the nature of the soil, and the kind of gallery to be driven, the position of the shaft frame nearest to the top of the gallery can be assumed, and its distance from the bottom of the shaft determined. Take this distance from the depth of the shaft, and the distance from the top of the shaft to the frame next above the gallery is determined. Divide this distance into equal portions, or nearly equal divisions, of such a length as may be deemed prudent for the frames to support; the number of these divisions will be the number of frames required.

Fig. 7.

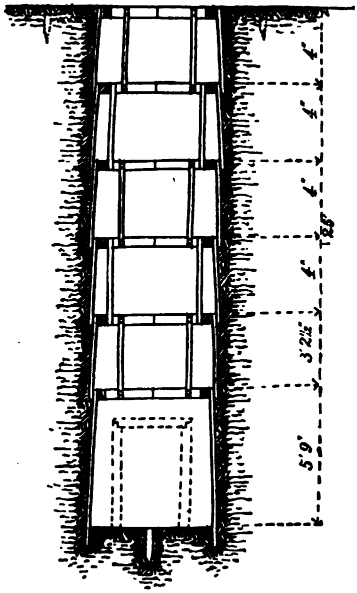


As an example, suppose the shaft is to be 25 feet deep, and a common gallery is to be driven from the bottom.

The height of the top of the cap-sill of the gallery above the ground-sill is five feet. The thickness of the sheeting is taken to be one and a half inches. The thickness of shaft frame may be taken to be six inches. Two inches of free space should be allowed between the top of the sheeting and the shaft frame, to facilitate the operation of pushing the sheeting in place. We have, therefore, for interior height of gallery, 4½ feet; for thickness of cap-sill, 6 inches; for thickness of sheeting, one and one half inches; for free space, two inches; and for thickness of shaft frame, six inches; total, five feet and nine and a half inches. Deducting this from twenty-five feet leaves nineteen feet two and one half inches, for the distance from the top of the shaft frame to the top of the shaft. Suppose four feet to be the limit allowed for the distance apart of the frames; the quotient obtained by dividing the distance just found, by four will give the number of frames required. In the foregoing example, there would be five—four which would be placed four feet apart, and a fifth placed a little over three feet distant from the fourth, and coinciding with the frame taken to be three inches above the cap-sill of the gallery.

The frames and sheeting being ready, the construction of the shaft is begun by marking its position upon the ground, care being taken to have two of its sides parallel to the direction of the proposed gallery. An excavation is then made large enough to receive the top frame, and is carried down for two or three feet. The top frame is laid in position, with its upper surface flush with the surface of the ground, and is held firmly in place by strong pickets driven near the ends. This having been done, the excavation is continued until a depth equal to the first interval is obtained, and then a shaft frame is inserted. At the middle point of each piece of a shaft frame there is a cut, called a **score**, by means of which, and a plumb line, the frames can be accurately placed one above the other. As soon as the second frame is placed, the sheeting is pushed down to its full extent, as shown in Fig. 8. At this stage, the sheeting rests against the top frame, but is kept away from the lower frame by wedges, a little thicker than the sheeting, making room for the insertion of the second set of sheeting. Before continuing the excavation, the shaft frame must be fastened to the upper one,

Fig. 8.



so that it will not change its position upon the earth being removed. This is done by means of four battens, two being nailed to each piece on opposite sides of the top frame, and to the two corresponding pieces of the shaft frame. Beginning with the top frame, the battens are fastened to the two pieces resting upon the others, or to those having the notches downward. These battens are then fastened to the pieces of the shaft frame which have their notches upon the upper sides. This arrangement of fastening the battens is carried out for the succeeding frames. The second frame being fastened, the excavation is resumed, and a third frame inserted, etc. The operation is continued until the requisite depth of shaft is obtained.

Sometimes the earth caves so badly as to require an **auxiliary frame** to be used. This frame is inserted about halfway between the positions occupied by the shaft frames, and when the lower shaft frame is placed the auxiliary frame is removed. The placing of the frame, and general method of using it, do not differ in principle from that of the ordinary shaft frame.

19. Construction of Galleries.—The construction of galleries differs in no way, in principle, from that of shafts. If the soil is loose, linings must be used; and these may be either made of cases, or of sheeting supported by frames. When the soil is firm, the lining need not be continuous, and in some cases may be omitted. This, however, is a dangerous method, and should be avoided if possible.

Previous to beginning work upon a gallery, its centre line, or axis, should be marked at the bottom of the shaft. This is done by driving small pickets at points which are determined by plumb lines let fall from the mouth of the shaft, and fine points marked upon the heads of the pickets. If the gallery is to be lined with cases, or with sheeting and frames, the first case, or the first frame, whichever may be used, is placed so that its inner edge is flush with the inside surface of the shaft.

When the case is used, just enough earth is removed to allow the ground-sill to be placed; then grooves are cut to receive the stanchions; and then a recess made for the cap-sill. A small excavation upon the upper side of the cap-sill, as well as behind the upper part of the stanchion, is needed to get the pieces framed together. If the horizontal plan, shown in Fig. 5, be supposed to occupy a vertical position with *b* at the bottom, it will illustrate the method to be used in placing a case in position in a gallery. The case being in position, the earth can be removed as far as the length of the case, and a second one be placed; the operation may be continued until the necessary length is obtained. If sheeting and frames are to be used, the same general method is followed. The frame is placed, and the excavation is carried on until a new one is to be used. If the soil is loose, **false frames**, similar to auxiliary frames, are employed, which are removed as soon as the second frame is in place.

20. Remarks.—The principles of construction used in galleries and shafts are easy of comprehension, but are accompanied by details which are frequently quite difficult of application. Manuals are prepared for engineers, giving the knowledge of the methods employed, the difficulties to be overcome, and the details of construction to be used; and the student is recommended to refer to these manuals.

It is especially necessary to prepare working drawings of all shafts and galleries for the guidance of the workmen. The projections of the axes of the galleries and branches should be carefully plotted, and all references, distances, and angles be distinctly written upon the drawings. Strict adherence to the details of the drawings should be required.

21. Mining Tools.—Miners require special tools for their work. The picks and shovels which are used by them are of the same general form as the ordinary ones, but are lighter. The miner's pick has a handle not more than two feet long, and does not weigh more than six pounds. The shovel has a blade about nine inches wide, and with handle, is not more than eighteen inches long. Its weight is about the same as that of the pick.

With these tools, a third, known as the **push-pick**, is used. This tool has a straight handle, with a heart-shaped blade, from three to four inches wide and six inches long, fastened to it—the whole being about two feet long. It is used to loosen the earth in recesses, like those made behind the cases when they are placed in position.

In addition to these mining tools, means must be provided to remove the earth from the galleries, and to raise it in the shafts. Hand-barrows, wheel-barrows, or small trucks may be used for the former; windlasses and buckets are used for the latter.

Means for ventilating and lighting the galleries, while the miners are at work, are necessary.

22. Mine Chamber.—The recess made to receive the charge is known as the **mine chamber.** Its position and size will depend upon the effect to be produced by the explosion of the charge, and the amount of explosive.

The centre of the chamber is usually placed on the same level with the floor of the gallery or branch leading to it. The chamber may be at the end of the gallery or upon one side.

The size of the chamber should be a little larger than the size of the charge, to allow the latter being placed in it. The more compact the charge, and the less spare room there is around it, the more effective will be the explosion.

23. Size of the Charge.—If a cubic foot of gunpowder weighs 57.6 pounds, which is the weight given in the manuals, one cubic inch of it will weigh .0333 of a pound. Knowing the number of pounds in the charge, we easily obtain the cubical contents which a box should have to be large enough to contain the charge. This is given in cubical inches, and if it be desired to have the box cubical in form, which is mostly the case, the inner edge of the box can be obtained, in inches, by simply finding the cube root of the product obtained by multiplying the number of pounds in the charge by three hundred.

24. Ventilation.—It is essential that good ventilation be kept up in the galleries while the miners are at work. Even in good soils and under favorable circumstances the air of the galleries becomes vitiated in a short time by the workmen themselves. To such an extent does it become so that it is not considered safe to drive a gallery further than about twenty yards without artificial ventilation.

When two galleries are driven parallel to each other, the ventilation may be improved by connecting the two by passages, which will produce a circulation of the air.

Communications made with the upper surface of the ground by holes bored through the upper part of the gallery will give relief.

These methods not being used, fresh air must be forced into the galleries in some way, as by means of bellows or by fans, which will drive the air into a hose and deliver it at the headings of the galleries. Any device which will remove the foul air near the headings and replace it by pure air, will be effective.

25. Lighting.—The operations of mining are carried on both day and night, and some provision should be made to supply the miner with light when he is at work. Lanterns are frequently used, but there is hardly anything better, all things considered, than pieces of candle, fixed in what is known as the **miner's candlestick.** This is a contrivance for holding the candle and at the same time arranged so it can be fastened on the band of the miner's cap, or stuck into the earth, or timber, of the sides of the gallery.

Tin reflectors may be used to throw the sunlight down the shaft and then into the gallery. This method is useful in daylight, but not at night. It is a method to be commended when it would be dangerous to carry ordinary lights into the galleries.

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CHAPTER III.

LOADING AND FIRING OF MINES.

26. Placing the Charge into the Mine Chamber.—If the chamber is naturally dry, and the mine is to be "sprung" in a very short time, the powder may be placed in bags, and the bags packed closely together in the chamber. Precaution should be taken to line the bottom and sides of the chamber with straw, or brushwood, to prevent any dampness reaching the powder. If the soil is damp the bags must be made water-proof by a covering of some substance impervious to moisture, where the material of the bag is not waterproof.

India rubber bags, large enough to hold one hundred pounds of powder, are frequently supplied with the mining stores.

When a box is used to hold the charge of powder, the powder is emptied from the bags into the box. The same care should be taken to prevent moisture reaching the powder as before, which may be done by making the box tight, and covering it with a coat of pitch, or similar substance. If the soil be very damp, a metal box is considered better than one made of wood. A cask, coated with pitch, forms a good receptacle for the powder in a damp place, the powder being poured into the barrel through the bung-hole.

Canvas bags are used for carrying powder to the chambers. They are made large enough to hold fifty pounds, and are carried upon the men's shoulders. When the charge is a very large one, the bags may be placed upon trucks and drawn through the galleries. Extra care should be taken to avoid accident, since a spark struck from a stone by the truck may result in a premature explosion.

As soon as the chamber is loaded, the means of firing it must be attended to. It may be fired by means of electricity, of a safety-fuze, or by a powder-hose. Whichever be the method adopted, the arrangement should be such that the subsequent operations will not disturb or injure it. This is so important a part of the mine it is recommended that the officer in charge of the mine should attend to it personally, and not intrust this duty to any subordinate, however faithful he may be.

27. Tamping.—Tamping is the name given to the operation of closing a branch or gallery, so that when the mine is fired its effects will be felt in the proper direction.

Tamping consists in filling **solidly** for a given distance the branch or gallery leading to the mine, with the material excavated from the galleries, with sand-bags filled with earth, with sods, or with any heavy substance. It is considered advisable to brace the sides of the gallery by diagonals, in addition to the tamping, so as to strengthen or increase the resistance of the whole solid tamping against the effect of the explosion.

The length of the tamping, or distance to which the gallery should be filled, is regulated by the line of least resistance of the mine to be fired. It is considered essential that the tamping should extend a distance from the chamber of at least one and a half ($1\frac{1}{2}$) times the length of the line of least resistance if it is well done. If the tamping is not solid, it is advised to increase this distance.

The operation of tamping may be discovered by the opposing miners, when mining and counter-mining are going on together, by certain noises, and by absence of the noise of the miners' picks. It is recommended, in such cases, that the miners' picks be kept going, giving the appearance of a continuation of mining, to mislead the enemy respecting the tamping.

28. Explosives.—Gunpowder, gun-cotton, and the compounds of nitro-glycerine may be used as explosives in mines.

Gunpowder is the principal one used in military mines, such as have been described. It gives more satisfactory results, less danger to those using it, and can always be procured from the supplies with the army.

Gun-cotton has the serious objection of making the ground unfit for further mining after it has been exploded, in consequence of the production of large quantities of carbon dioxide.

The compounds of nitro-glycerine are dangerous to the miner, and, for such mines as are now under consideration, possess no peculiar advantages over gunpowder. In exceedingly damp or in wet places they would be employed.

29. Methods of Exploding Mines.—**Electricity** will always be used when practicable; but as the appliances are not always at hand, other methods have frequently to be adopted. The most general of these methods (which can be most easily improvised, and the materials obtained) are the **powder-hose**, and the **safety-fuse.**

The **powder-hose** is a sausage-shaped bag, from a fraction of an inch to an inch in diameter, made of linen, in lengths of twenty feet, and filled with powder. Where a longer piece than twenty feet is required, two or more of these lengths are spliced together.

One end of the hose is placed in the middle of the charge, the hose passing through a hole in the box, and being fastened firmly in the hole by a wooden wedge. It is protected from the tamping, and from injury in the gallery, by being inclosed in a wooden box, called the **hose-trough.** This trough may be made in the same manner as a common box; or it may be made by cutting grooves one-half the size of the cross section of the hose in the sides of planks. The planks are then fitted together, inclosing the hose in the grooves made in their surfaces. In putting on the top of the hose trough, or fitting the planks together, care should be taken to fasten them together by wooden pins, and not to use nails.

The hose-trough is carried along the floor of the gallery, out of the way, and covered with earth.

When the mine is to be fired, the outside end of the hose is uncovered, and an inch or two of it exposed. A slow-burning fuse, or a piece of port-fire, is inserted, and so secured to the end of the hose that no fire can reach the powder in the hose until the fuse or port-fire burns down to it. The fuse, or port-fire, is then lighted; and after a few seconds of burning it sets fire to the powder in the hose, which fires the mine.

The powder-hose burns so rapidly that, for short distances, it may be regarded as instantaneous in its action. It is for this reason that the port-fire, or the piece of fuse, is used, to give time to the men to escape after firing the match.

The powder-hose can be made from materials on hand, and is a method which can be employed when no better one can be improvised.

The *safety-fuse* furnishes a far better method than that of the powder-hose for exploding mines. This fuse consists of a train of gunpowder, inclosed in strands of rope which have been made water-proof. Quantities of it are made for ordinary blasting purposes, and are furnished with miners' supplies. That usually employed is manufactured in lengths of twenty-four feet, and, when fired, burns at the rate of four feet a minute, or six minutes to the single length. When a longer piece than twenty-four feet is required, it is obtained by splicing two or more of the lengths together.

When used, one end is inserted into the charge and firmly secured in this position. The other end is cut diagonally across, and then slit up for two or three inches. The powder is loosened in this end by gently pressing the fuse. It is then fired by application at once to the powder, or by means of a slow match or other device.

Precaution should be taken to keep it from being injured by the tamping, or disturbed in the gallery after it has been laid in place.

The **best** of all methods is that of **electricity**; but this method is far from always being practicable.

In the case of electricity, the mine is fired by the explosion of a fuse placed in the middle of the charge, which fuse is fired by an electric current.

These electric fuses are of two general kinds, the **tension**, and **resistance** fuses. Both kinds are similar in their general construction, which consists of a case containing an explosive, into which run two insulated wires, connecting outside with the wires of the electrical apparatus, and being without insulation on the inside of the case. The uninsulated, or naked, wires inside are surrounded by a sensitive fulminate. In the tension fuse there is a break between the ends of the two wire on the inside; in the resistance fuse, the ends of the wires are connected by a fine platinum wire, of dimensions much smaller than the main wires. The electric current passing through the wires, meets with the break, and passes from one to the other by a spark, which explodes the fulminate, fires the fuse and the charge of the mine. Or, meeting the smaller platinum wire, the current, by the resistance offered, heats the wire red hot, which fires the fuse and charge.

The tension fuse is used in connection with the appliances which produce frictional electricity; and the resistance fuse with those which give the voltaic current. Some fuses are made which can be fired by either form of electricity.

The fuse being placed in the middle of the charge and connected with the wires, these latter are carefully guarded against injury from the tamping, and from any interference. The wires from the battery to the charge should be carefully tested before they are put in position, and great attention paid to their perfect insulation.

When several mines are to be exploded simultaneously, there is nothing equal to the method of electricity for doing it. In the other methods, care must be taken to have the safety-fuses and powder-hose all of exactly equal lengths and all fired exactly at the same moment.

With electricity the action is so rapid that no differences in the lengths of the wires will give appreciable differences in the times of explosion.

In this case of simultaneous explosions the wires may be arranged to form a continuous circuit, including all the fuses; or they may be arranged to form a separate circuit for each one; or be arranged to combine both the continuous and separate circuits. The latter arrangement is the one generally preferred.

The machines used to generate the electricity are the friction machine, the voltaic battery, and the magneto-electric machine. Descriptions of these appliances are given in works upon electricity.

CHAPTER IV.

GENERAL CONDITIONS OBSERVED IN A SYSTEM OF MINES.

30. Mines in Early Times.—History records the use of mines in ancient times in connection with siege operations. Reference is made to their use by Alexander the Great, by Cæsar, and by other generals of note in history. They were freely used in the middle ages in the attacks of castles and walled cities.

The object to be attained by the use of mines during those periods was either that of a breach in a wall, or that of a subterranean passage which would allow the besiegers an entrance into the interior of the place, and an opportunity of capturing the place by surprise.

When a breach in the wall was the object, the mines were driven under the foundations, and these foundations held up by supports made of timber. When the excavation was sufficiently large for the purpose the besiegers set fire to the supports. These being burned, the foundations fell into the excavation made, and a breach in the wall was effected.

31. Use of Gunpowder.—Mining operations received a great impetus from the introduction of gunpowder in military operations, and became, in a short time, one of the most useful methods of attack in reducing a fortified place.

One of the first instances of the effective use of mines charged with powder was the employment of them in what is known as the seventh siege of Naples, in 1503.

This siege was undertaken by the Spaniards to wrest Naples from the French, who occupied the city at that time.

The French retreated, at the approach of the Spaniards, into two strong castles, which castles were at once fiercely attacked by the Spaniards and vigorously defended by the French. There was an engineer in the Spanish army by the name of Pedro of Navarre, who had seen mines used by the Genoese, in 1487. These mines had failed, but this officer believed the failure to be due to the ignorance of the miners and not to the method. He persuaded the Spanish General, Gonzalvo, to allow a trial of them to be made. So successful was he in the use of the mines, that both castles were blown up and the defenders destroyed.

From this time mining became a popular method of attack, and was soon used for the defence. As early as the beginning of the 17th century systems of mines were devised to be used in the defence.

A most remarkable use of mines, both by the attack and by the defence, is mentioned in the history of the siege of Candia (1667–9). It is stated that there were 1,300 mines sprung during this siege.

The experience there acquired led to the adoption of certain rules for the construction of mines; but as these rules were defective, Vauban caused many experiments in mining to be made. By means of these experiments he corrected the rules then in use, and added new ones. From this time mining operations became a science, and systems of mines were devised to be used in the defence of a work. In fact, a system of mines for the defence ever afterwards formed a part of the plan of defence of every fortified place. The application of mining to the defence has, however, been greatly restricted, in consequence of the time and labor required for the construction of the mines, the large number of skilled miners to be employed, the extra supply of powder to be kept, and, chiefly, the great cost to be incurred.

32. General Arrangements.—The term **counter-mines** is used to designate a system of mines designed for the defence of a work.

Many plans have been suggested, and of course these plans are modified by the surroundings of the fortification and the circumstances of each case.

A general arrangement has been suggested, and is as follows:

From the point of attack a series of galleries are to be driven under the glacis, and in the direction of the capital of the salient of attack. The directions of these galleries may be parallel to that of the capital, or they may diverge from the salient, taking a fan-shaped position in plan. They start from a commodious gallery behind the counterscarp wall, and are connected at intervals by galleries parallel to the counterscarp. These connecting galleries are known as **transversal** galleries, and serve as communications between the radial galleries, and as a means of providing a free circulation of air.

When the galleries are extended their full distance, the extremities should be so near to each other that the enemy's miners cannot pass between them without being heard. The sound of a miner's pick at work in ordinary soil can be heard underground at a distance of forty feet, if no attempt is made to muffle the sound. If the ends of the galleries are not near enough together, branches are to be driven, narrowing the space, and from which branches the movements of the enemy can be heard. Galleries of this class are termed **listening** galleries.

The general plan supposes the extremities to be near, or under, the ground which the enemy would occupy with their third parallel. A series of mine chambers is constructed near the extremities of these galleries, and they are so arranged that they will, by their explosions, break up all the ground over them. Care is taken to arrange the chambers, and to proportion the charges, so that the explosion of any one mine, or group of mines, shall not injure any other mine, or group of mines, that may be required at a later period.

As an illustration of this general arrangement, take the case shown in Fig. 9, in which **B** is the point of attack.

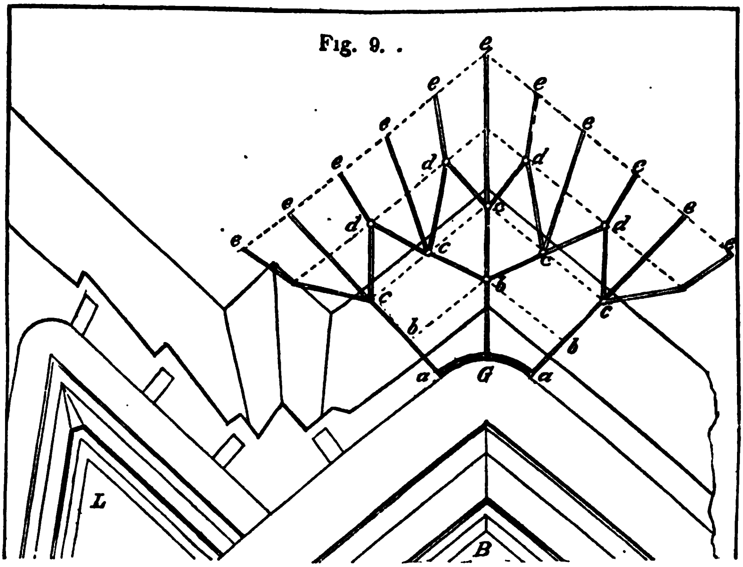


Fig. 9.

Since a limit has to be assumed for the length of the galleries, suppose the line *e*, *e*, *e*, etc., to be the limit beyond which it is not expected to drive the galleries.

This line being marked upon the plan, is divided into intervals, such that the enemy's miners cannot work in the intermediate space without being heard from the galleries at the points of division, *e*, *e*, etc. Take this interval at twenty yards. The points, *e*, *e*, *e*, etc., denote the extremities of the galleries which run parallel to each other, or radiate from some given point. In the figure, they are taken to radiate from the salient of the bastion magistral. They might have been drawn perpendicular to the counterscarp.

At a distance of twenty yards, or thereabouts, from *e*, *e*, etc., draw the line *d*, *d*, etc. This line will represent the axis of the outer transversal gallery.

As these radial lines are converging, it will be a saving of labor to make a slight change in the directions of some of the galleries. Beginning at the gallery whose axis coincides with the capital, lay off from the outer transversal gallery a distance inward equal to twenty yards, or a little greater, and this gives a point of the inner transversal gallery. Let the two adjacent galleries be joined to the capital gallery at *c*.

Run the galleries adjacent to these latter direct toward the salient for twenty yards, and at the points *c*, *c*, etc., let the galleries next to them on each side join the straight galleries. Continue this method until the extremities of the limiting line are reached.

The three galleries on the right, and the three on the left, communicate with galleries leading direct to the extremities of the counterscarp gallery *a*, *a*, at **G**.

The intermediate galleries connect with the counterscarp gallery by the gallery, *b* **G**, whose axis coincides with the capital of the salient.

The radial galleries are descending galleries, with an inclination such as to place the extremities from thirty to forty feet below the surface of the ground. The deeper the galleries are placed, the less liable they will be to meet with injury from the enemy's mines.

The arrangement of the galleries, as shown in Fig. 9, has for its object to have groups of mines independent of those upon the right and left of them, and, at the same time, to allow direct communication with each group.

It is possible that a third transversal gallery may be necessary. If it should be required, it would occupy some such position as *b*, *b*.

The counterscarp gallery, G, from which the radial galleries depart, should be large and roomy, as it is to serve as a depot of supplies, as well as a means of communication. The radial galleries, from *a* to *c*, are great galleries, and from *c* to *e*, are common galleries.

The transversal gallery *c*, *c*, *c*, etc., is a principal gallery, and the one at *d*, *d*, *d*, etc., is a common gallery.

The plan of having the galleries to radiate from the salient, or have directions perpendicular to the faces, is considered a better one than having them parallel to the capital. If the enemy succeeds in blowing in the sides of the galleries, the trenches which are formed can be more easily enfiladed from the bastion in the former than in the latter case.

A similar arrangement of countermines may be adopted for any other salient exposed to an attack by regular approaches.

33. Mines of Attack.—Mines are sometimes used by the besiegers to gain ground, when they fail to do so by the method of sapping. The French, at Sebastopol, resorted to mining to establish their fourth parallel, being unable to gain the ground by sapping.

The general principles may be briefly stated to be:

To make the advance by several parallel galleries, and to use listening galleries on the flanks;

When near the countermines of the besieged, to push forward the advance as rapidly as possible, and hasten the construction of over-charged mines, to blow in the galleries of the countermines;

Before springing the overcharged mines, have everything ready to occupy and intrench the craters at once, and to construct shelters for the troops who are to occupy them.

General Todleben remarks that this advance is accompanied with more or less loss among the besiegers, "but too much prudence and circumspection for the sake of avoiding loss will always result in complete failure for the besiegers."

CHAPTER V.

MILITARY DEMOLITIONS.

34. Demolitions.—The term **demolition,** derived from the verb "to demolish," is applied to those acts in military operations which have for their object the destruction of any structure. The structure may be in the way of some military operation and will have to be removed, like a building on the exterior of a fortification and within range of its guns; or it may be an obstacle, like that of a revetment wall, which must be overcome, etc.

Demolitions are usually divided into two classes, **deliberate** and **hasty**; or those in which time is taken to complete the act, and those in which the time is limited for completing the demolition. The latter class is used particularly in active field operations, where the demolitions are intended to impede an enemy's advance, or cripple his movements in some way.

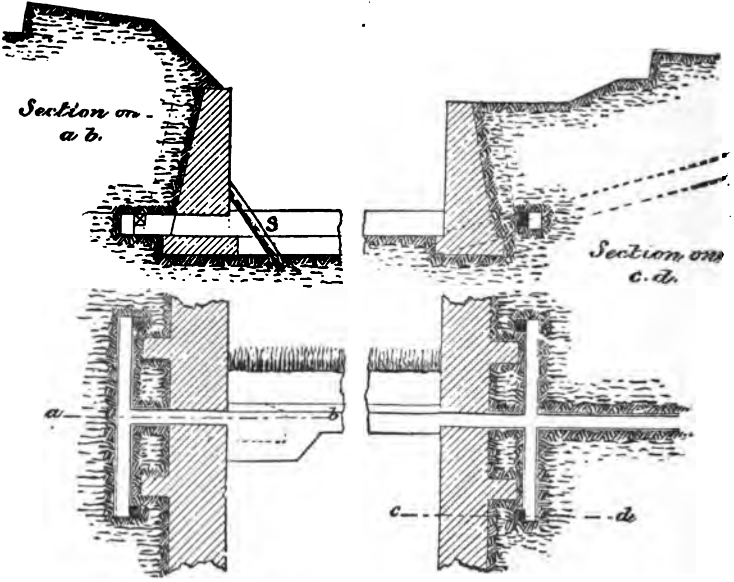
35. Breaching by Demolitions. — Breaches are made ordinarily by the use of cannon. Sometimes the breach cannot be effected by this method, and must be made by mining.

When the besieger has reached the ditch, which he does by means of a great gallery, he pushes a sap across the ditch to the foot of the scarp wall. A shelter, **S**, (Fig. 10), is arranged, under cover of which the miner can work to drive a gallery under the scarp wall, or to break through it.

The French authorities recommend that the miner pass under the wall by sinking a shaft, and then to drive a gallery. If water or rock be present this plan could not be carried out, and the miner would be compelled to break through the wall.

The miner, in this case, enters the wall by a horizontal gallery, about four feet high and two feet wide, perpendicular to the face of the wall. As soon as he breaks through the back of the wall, he drives galleries along the back, to the right and left, to the points where the mine chambers are to be made (Fig. 10).

Fig. 10.



Vauban placed the mine chambers at a distance of from one third to one half the height of the wall from the back, or about on a line with the back of the counter-forts. Cormontaigne followed the same general plan, placing the mines on a line with the backs of the counter-forts, and about thirty feet apart.

Where there are no counter-forts, the mine chambers may be placed as stated; but if there are counter-forts, the chambers should be near each counter-fort, or every second one, at least. The bottom of the mine chamber is placed about three feet above the bottom of the ditch. The charge should not be placed in contact with the masonry, or the advantage of shaking and loosening the earth resting against the wall will be lost. All agree that it is better to use too large a charge than one which is too small. The length of the tamping should be equal to twice the line of least resistance, and when this is not practicable, the charge must be increased accordingly. The distance of the charge below the terre-plein should be at least twice the horizontal distance from the charge to the face of the wall.

Mines placed in this way, with heavy charges, will, when fired, blow down the scarp wall and loosen the earth, so that a practicable breach can be made. If it be desired to breach the counterscarp wall, the same general method can be employed as indicated in Fig. 10.

If the scarp wall is a detached one, shafts may be sunk at intervals, and charges placed under the foundations. If the wall is not a thick one, the charges may be laid at the foot of the wall, or in grooves made in the face, and then covered with earth. The earth acts as a tamping, and is piled upon the charge in such quantities as to make the line of least resistance pass through the wall.

Demolitions are oftentimes necessary in consequence of the abandonment of a work. The object to be attained is to make the work useless to the enemy. The demolition of revetment walls is effected more cheaply, and as satisfactorily, by placing the charges in the wall, instead of behind, or against it.

Arches can be destroyed by mining the piers, the crown, or the haunches. A single arch is best destroyed by a mine, or a series of mines, placed in the haunch.

Demolitions of magazines, buildings, etc., do not differ in principle from the method described for destroying a wall.

APPENDIX.

FORTIFICATION DRAWING.

1. General Principles.—In a general sense, drawing has for its object to make a representation of some particular construction or given figure upon a surface, in such a manner as to give to others an idea of the form of the thing represented, and of the appearance of the parts of which it is composed. The methods by which the representation is made are known as perspective drawings, orthogonal projections, isometric projections, etc., according to the rules followed in making the representation.

The orthogonal projection is the method followed in fortification drawing; but modified in its application by making use of only one, instead of two, planes of projection. The plane taken is the horizontal one; the vertical plane being discarded, and in its stead figures are annexed to the points, giving their height above or below the plane of projection. This is the same method as that followed in hydrographical and topographical drawing, and is known by the name of "**one-plane descriptive.**"

A fortification drawing may be divided into three parts: the geometrical construction of the drawing, the graphical part, and the coloring.

The geometrical construction has for its object to locate upon the drawing all points, lines, and surfaces, of the fortification, so that they shall have, in the drawing, exactly the same relative positions that they have in the work, or are to have when the fortification is completed.

A geometrical construction of this kind will give a good conception of the work to any one who examines it.

When it is said that the vertical plane of projection is discarded, it is meant that it is not used as the ordinary method employs it. Profiles, sections, and elevations are useful to show the relation between the relief and the site, and are necessary to illustrate the details of parts of the fortification. These are made from the plan, but upon a much larger scale than the one employed in the construction of the plan.

2. Advantages.—There are certain advantages which are gained by discarding the ordinary vertical plane of projection. These advantages may be all summed up under two heads, viz.: the **simplification** of the drawing, and the **accuracy** of the vertical dimensions given by this method.

The simplification is evident, because there will be a less number of lines to draw, and less confusion in the lines drawn.

The accuracy is evident, because the figure annexed to a point tells, within the one hundredth part of a foot, its position above or below the plane of reference.

The vertical dimensions of a fortification are small compared with its horizontal ones. Those projected upon a vertical plane of projection, as in the ordinary method, would give a confused figure, and from the near parallelism of many of the lines, would make the intersections of many of them difficult to determine.

The ease with which a point represented upon the drawing can be located upon the ground in practice is worthy of notice. A bench-mark and certain points are fixed upon the site. From these fixed points, either by the method of latitudes and departures, or by that of triangulation, the position of

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the point is determined. A line of levels is used to connect the point thus formed with the bench-mark, and its difference of level, taken with respect to the plane of reference, is found. The difference thus found is deducted from its reference given upon the drawing, and the remainder gives the distance the ground must be excavated, or raised, to get the true position of the point.

3. **Plane of Reference.**—The horizontal plane upon which the lines of the fortification are projected is called the **plane, of reference.**

The position of this plane is entirely arbitrary, and is taken in fortification drawing to be above, or below, every point of the fortification.

In the drawings made by the United States Corps of Engineers the plane is taken below the work.

4. **References.**—The numbers written upon the plan to express the distance of the points above the plane of reference are called **references.**

The unit employed in this country is the linear foot and its decimal parts. In writing the reference it is usual to omit the sign of the unit, it being understood to be the foot.

This method is considered advisable for simplicity, and because it prevents any mistake being made between a reference and a horizontal distance, this latter having the unit of measure indicated.

5. **Reference of Points.**—The position of a point is accurately determined when its projection is known, and the distance above the plane of reference is given.

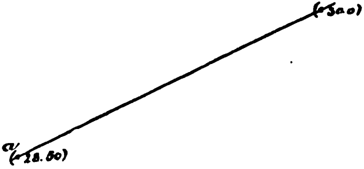
It is usual to represent a point upon the plan in this manner, viz.: (·25.63), (·38.0), (·27.50), etc., the point of projection and the reference being inclosed within a bracket.

Whenever the reference is a whole number, it is written with one decimal place, as (·38.0); in all others, it is written with at least two decimal places, as (·25.63), (·27.50), etc.

As a general rule, the projection of a point in plan represents only a single point. It happens sometimes that two or more points lie upon the same vertical line of projection. In this case as many references are written as there are points projected, the difference in numbers showing the true positions of the points.

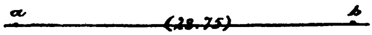
6. **References of Lines.**—From geometry, a right line is fully determined when two of its points are fixed. It follows that when the projections of any two of its points are given, and the references are known, the right line passing through the points is fully determined. Thus, in Fig. 1, the projection *ab* of the line, and the references (28.50), and (30.0), fix the line in space.

Fig. 1.



If the line is a horizontal one, the projection of the line and the reference of any one point are sufficient to fix it. Thus, in Fig. 2, the line *ab* being the projection, the reference of any point (28.75) fixes its position.

Fig. 2.



Since all the points belonging to this line have the same height above the plane of reference, it is usual to write the reference along the line, as shown in the figure.

7. **Problem.**—A right line being given by its projection and the references of two of its points, **it is required to determine any other point of the line.**

To determine any point not given, let *ab* (Fig. 3) be the given line, upon which other points are to be determined.

There will be two cases:

1. Assuming the projection of a point, to find its reference.

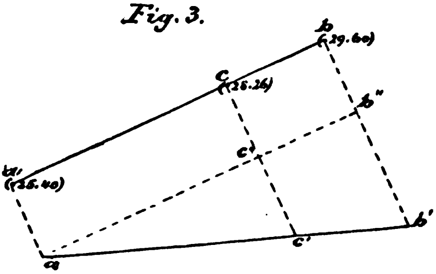
2. Assuming the reference to determine the projection.

First case. Assuming c as the projection, it is required to determine its reference.

Suppose the vertical projecting plane of the line ab to be revolved around some one of its horizontal lines until it is parallel to the plane of projection. The point a will fall in a perpendicular through a, and at some distance as aa'. The point b will fall at some point as b', and the line $a'b'$ will be the revolved position, in the horizontal plane containing the axis of revolution, of the line projected at ab. Through c draw the perpendicular cc', and c' will be the point, on the revolved position of the line, which is projected at c.

From the figure, $a'b'' : a'c'' :: b''b' : c''c'$, in which proportion all the quantities are given excepting $c'c''$. This distance is easily determined from the proportion, and when added to the reference of a, gives the reference of the assumed point c.

Fig. 3.



Second case. Assuming the reference, find the projection of the point.

Take the same figure, and assume the reference to be (28.26) for some point between a and b. From the figure, $b''b' : c''c' :: a'b'' : a'c''$, in which case all the terms are known excepting $a'c''$. Finding this value, and laying it off from a, the projection of that point whose reference is (28.26) is determined.

8. Use of the Natural Tangent.—If the projection of a right line, the reference of one of its points, and the angle which the line makes with the horizontal plane, be given, the line is fixed. This inclination of the line or angle with the horizontal, is generally expressed in terms of the tangent of the angle. The line *ab* in Fig. 3 being oblique to the horizontal plane, makes an angle with that plane. The tangent of this angle is equal to $\frac{b'b''}{a'b''}$, or, equal to the quotient obtained by dividing the difference in reference of any two of its points by the horizontal distance between them. This horizontal distance is equal to the horizontal projection between the points.

The expression thus obtained for the tangent is called the inclination, or the **declivity**, or the **slope**, of the line, and is expressed under the form of a common fraction, as ½, ⅓, ⅘, etc. It is usually read, a slope of **one on two**, **four on five**, etc.

The numerator of the fraction is the difference of reference, the denominator the difference of horizontal projection, and both are given in the same unit.

An examination of the two proportions, given in the last article, taken from (Fig. 3), shows how the first and second cases there named can be solved by the use of the slope, or declivity, of the line.

From these proportions, we have :

$$c'c'' = a'c'' \times \frac{b'b''}{a'b''}, \text{ and } a'c'' = c'c'' \times \frac{a'b''}{b'b''} = c'c'' \div \frac{b'b''}{a'b''}.$$

Hence the following rules :

1. To find the difference of reference of two points, the projections of the points and the slope of the line being given, *multiply the horizontal distance between the points by the slope of the line.* This horizontal distance is the same as the distance between the horizontal projections of the points.

2. To obtain the horizontal distance between two points, the references of the points and the slope of the line being known, *divide the difference of the references of the points by the slope of the line.*

Let it be required, for example, to determine the reference of the point projected at *c* (Fig. 3), supposing the slope of the line and the scale upon which the projection is made to be known.

Assume that this slope is ½, and that the distance *ac* is 5'.72, obtained by measurement with the scale. The difference of reference by the rule would be $5'.72 \times \frac{1}{2}$, which is equal to 2'.86. This difference added to the reference of *a* will give the reference of *c*.

No example is necessary to show the method of obtaining the horizontal distance between two points, since the operation is identical with that just described.

9. Scales. — Geometrical constructions, to be accurate, should be drawn to some scale. The particular scale to be used will depend upon the size of the drawing which is required.

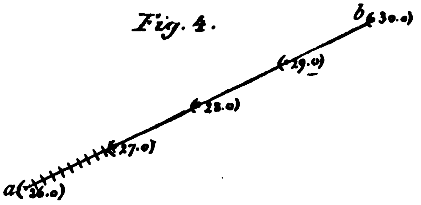
If the drawing is to be made of such size as to admit one linear inch of the drawing representing ten yards of the object to be represented, a scale of equal parts (each part being equal to one inch in length, and one of the equal parts being subdivided into tenths, twelfths, etc.), should be used in the construction of the drawing. Such a scale would allow dimensions of one yard or greater to be taken off and applied to the drawing. If dimensions of less length are required, they may be taken off approximately, or the use of a diagonal scale of equal parts may be used for that part which is subdivided into tenths of inches. Using this scale, the drawing would be said to have been constructed upon **a scale of one inch to ten yards**, or, of $\frac{1}{360}$.

Two scales are spoken of in this method of one-plane descriptive; the **horizontal** scale, and the **scale of slope,** sometimes called scale of declivity.

The horizontal scale is constant for the same drawing. The scale of slope varies with the line or plane to which it belongs, being greater or less according to the slope it represents. Its unit of division is the distance, whatever it may be, measured upon the projection of the line, between any two of its points, the difference of reference of which is **one** foot.

10. Scale of Slope of a Right Line.—To construct a scale of slope of a right line, take the right line *ab*, shown in (Fig. 4), which is given by its projection and two of its points, the references of which are (26.0) and (30.0).

Fig. 4.



Measure the distance between *a* and *b*, and divide this distance into four equal parts, which lay off along the line from *a* to *b*. The points of subdivision will correspond to points whose references taken consecutively differ from each other by one foot. Mark the references (27.0), (28.0), etc., at the points thus determined, and subdivide one of the subdivisions into ten equal parts. The scale of slope is then completed and may be used.

If the references of the points *a* and *b* are not whole numbers, determine two points upon the line whose references shall be whole numbers, and proceed to construct the scale as just described.

11. Use of Scale of Slope.—The scale of slope is useful in determining the reference of any point assumed upon the line of projection, and the converse. Assume a point on the line *ab* between (28.0) and (29.0). Its reference is between these numbers, and is obtained by taking a pair of dividers, measuring the distance from either (28.0) or (29.0) to the assumed point. Apply this measure thus obtained to the unit which is divided decimally, and find the number of divisions it contains. This number will give the number of tenths of a foot that the point, whose projection is assumed, is above (28.0), or below (29.0), according as the distance has been measured from the one or the other.

If this measure taken off does not contain an exact number of tenths, an approximate number of hundredths can be added, by estimating the fractional part of the subdivision included by the measure.

A similar process will determine the projection of a point when the reference is assumed.

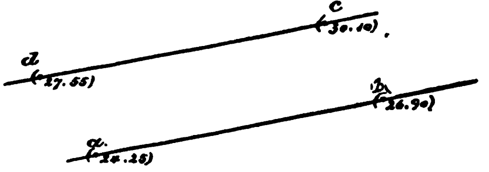
It will be observed, from (Fig. 4), that the horizontal distances between the points of the line are given from the scale of the drawing. Hence, if the distance between (28.0) and (29.0) is four feet, the slope of the line is known at once, or is ¼. Therefore, when the scale is constructed, the slope of the line becomes known at once, whence the name of "the scale of slope."

12. Problem.—Let it be required **to draw a right line through a given point and parallel to a given right line.**

From geometry we know that the projections of two parallel lines on the same plane are parallel, and the slopes made by the lines with the same plane are equal.

Let *c*, (Fig. 5), be the given point, through which a right line is to be drawn parallel to the line *ab*. Through *c* draw *cd* parallel to *ab*; it will be the projection of the required line. Lay off from *c* a distance *cd* equal to *ab*. Since the required line must have the same slope as the given line, the point *d* must be as far below the point *c*, as *a* is below *b*. The difference of reference of *a* and *b* is 2'.55, which being deducted from (30.10), the reference of *c*, gives (27.55) as the reference of *d*. Writing this reference at the point *d*, and inclosing it in a bracket, the problem is solved.

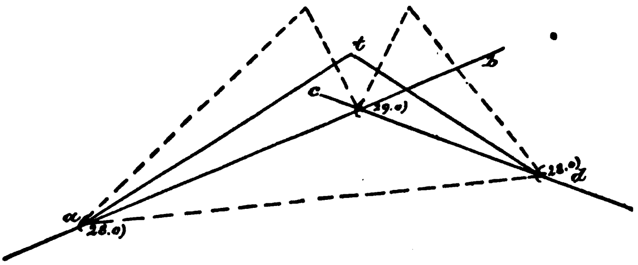
Fig. 5.



13. Problem.—Let it be required **to find the angle between two right lines which intersect.**

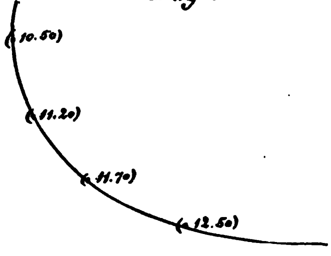
The true length of any portion of a line, included between two points in projection, is the hypothenuse of a right-angled triangle, in which the portion included is the base, and the difference of reference between the points is the perpendicular. It is required to find the angle made by the lines *ab* and *dc*, intersecting at a point whose reference is (29.0) (Fig. 6).

Fig. 6.



Find points on the two lines which have a common reference, but not (29.0). Join these points by a straight line. This line is horizontal, and is projected in its true length. Find the true lengths of the lines between the points of intersection and the points of same reference. With these true lengths, and the horizontal line, construct a triangle. The angle at its vertex will be the required angle.

Fig. 7.



14. Curved Lines.—Curved lines sometimes have to be represented. They are represented like right lines, by their projections and references. (Fig. 7.) This method is only accurate for curves when we know the law of their generation. When the curve is known only by points, the representation is merely an approximation, being simply a polygon of a great number of sides.

15. Planes.—A plane is fully determined when:

1. Any two of its right lines are given; and
2. Any three of its points, not in the same right line, are given.

The planes used in fortification drawings are of two general kinds—those limited in extent, and those to which no limit is given.

When the planes are limited, they are ordinarily represented by the bounding lines which limit them.

When they are not limited, they are represented by horizontal lines cut from the planes by equidistant horizontal planes, and by scales of greatest slope. Having an oblique plane given, it is easy to determine the position of a horizontal line, by finding two different points having the same reference and joining them by a straight line.

A straight line drawn in the given plane, and perpendicular to this horizontal line, will have its projection perpendicular to the projection of the horizontal. The angle made by this perpendicular line with its own projection is the measure of the angle made by the oblique plane with the horizontal plane of projection, and is the greatest angle that can be made by any right line of the plane with the plane of reference. This perpendicular coincides therefore with the line of greatest slope of the oblique plane, with reference to the horizontal plane, and is therefore called the **line of greatest slope** of the plane.

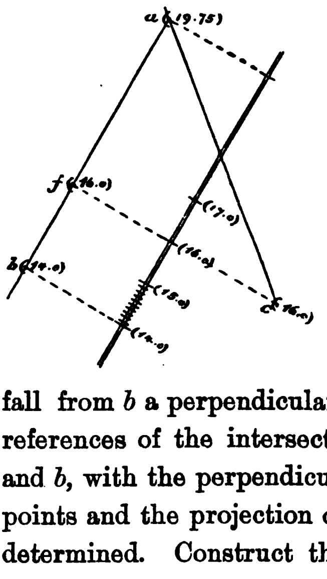
If the scale of slope of this line be constructed, it may be taken to represent the scale of slope of the plane to which it belongs, and to fix the position of the plane. And, since it gives at once the tangent of the angle made by the plane with the plane of reference, it is termed the **scale of slope,** or scale of greatest slope, of the plane.

Planes are described, as in the case of right lines, by their slopes; a plane of $\frac{1}{4}$, of $\frac{1}{6}$, of $\frac{3}{2}$, etc.

16. Construction of Scale of Slope of a Plane.—Let it be required **to construct the scale of slope of a plane when three of the points of the plane are given.**

Let *a* (19.75), *b* (14.0), and *c* (16.0), (Fig. 8), be the three given points. Join *a* and *b*, and *a* and *c*, by the lines *ab* and *ac*. Since the three points *a*, *b*, and *c*, are in the plane, the two lines *ab* and *ac* lie in the plane. Find a second point on each of these lines, having the same reference, and let *f* and *c* be these points. Join them by the straight line *cf*; this will be a horizontal line of the plane.

Fig. 8.



Any straight line drawn perpendicular to this horizontal will give the direction of the scale of slope.

Through any point on the horizontal, draw a perpendicular. Let fall from *b* a perpendicular upon this line just drawn. The references of the intersections of the horizontals through *f* and *b*, with the perpendicular, will be (14.0) and (16.0). Two points and the projection of the line being given, the line is determined. Construct the scale of slope of this line, and this scale will be the scale of slope of the plane.

The scale of slope of a plane is distinguished from that of a line of the plane by drawing two fine parallel lines near to each other (Fig. 8), and crossed at the subdivisions of the scale by short lines, which are portions of the horizontals of the plane.

The use of the scale of slope of a plane is similar to that mentioned for the line. The difference of references between two horizontal lines of a plane when the projections are given, or the horizontal distance between the projections when the difference of references is known, can be quickly obtained when the scale of slope is known. From this scale the slope is obtained, and this is used as a multiplier, or as a divisor, according to the conditions of the problem.

The method used to determine a plane when two of its lines are given, that is to construct the horizontals and scale of slope of the plane, is similar to that just given for three points.

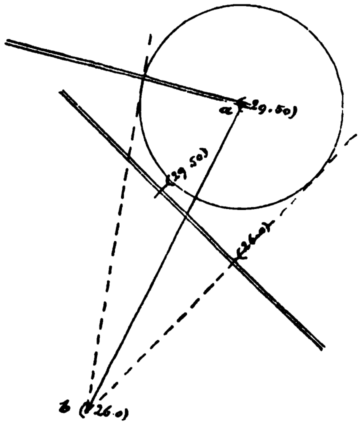
17. Problem.—It is required **to pass a plane with a given slope through two given points.**

Let *a* (29.50) and *b* (26.0), (Fig. 9), be the given points and the greatest slope to be $\frac{3}{1}$.

The horizontals of the plane having the references (29.50) and (26.0) must pass through the points *a* and *b* respectively. The difference of references of these points divided by the slope gives the distance, in horizontal projection, between these horizontals. The difference is 3′.50, which divided by $\frac{3}{1}$, gives 1′.16.

To find the horizontal whose reference is (26.0): from *a* as a centre, describe an arc with a radius of 1′.16, and from *b* draw a tangent to this arc; the tangent thus drawn is a horizontal of the plane whose tangent is $\frac{3}{1}$. The direction of the scale being known, and the references of *a* and *b* having been given, the scale can be constructed in the usual manner.

Fig. 9.



If the difference of references is very slight, it would give an easier and more accurate construction to find a horizontal considerably above, or below, both points. Then determine the radii of the arcs to be employed, describe the arcs, and draw a tangent to them for the horizontal.

If the slope of the line joining the points is the same as that of the plane, the horizontal constructed will be perpendicular to the line. That is, the line joining the points will be the line of greatest slope, and there is only one plane that can fulfill the conditions.

If the slope of the line joining the points is greater than that given to the plane, there will be no solution to the problem. In other words, it is an impossible problem.

When there are two tangents, there are two solutions apparently, but in reality one is the slope and the other is its supplement, depending upon the way the angle is measured.

In both of the foregoing problems it is seen that the solution depends upon finding a horizontal and a point of the plane not on this horizontal, and then dividing the scale into equal parts. This is the method that would be used for other problems of a similar nature relating to the plane.

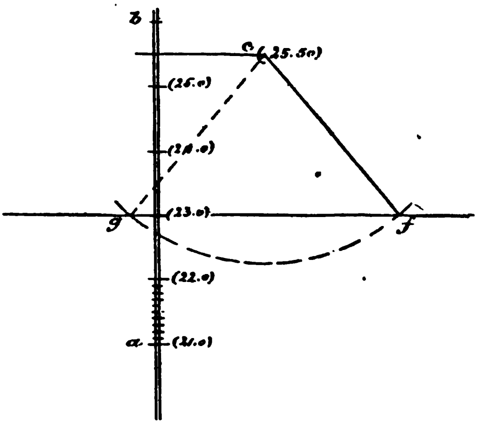
PROBLEMS OF THE RIGHT LINE AND PLANE.

18. Problem.—Through a point in a given plane, it is required **to draw a right line which shall lie in the plane, and have a given slope with the plane of reference.**—Let *c* (25.50), (Fig. 10), be the given point in the plane given by its scale of slope, *ab*; the line required is to have the slope of ½.

Draw the horizontal (25.50) of the plane passing through the given point, and any other horizontal as (23.0). The projection of the line must pass through *c*, and the length of the projection included between any two horizontals must be equal to the difference of their references divided by the slope of the line. The difference of references of the horizontal (23.0) and (25.50) is 2′.50, which divided by ½, gives 5′. With *c* as a centre and with a radius of five feet, describe an arc. It will cut the horizontal (23.0) in two points. Join these points with *c* by straight lines, and they will be the projections of two lines which satisfy the condition of the tangent being equal to $\frac{1}{2}$.

If the arc described is tangent to the horizontal, there is only one line, and it is parallel to the scale of slope. If the arc described does not touch the horizontal, the line represented by its radius has a greater slope than the plane, and the problem is an impossible one.

Fig. 10.

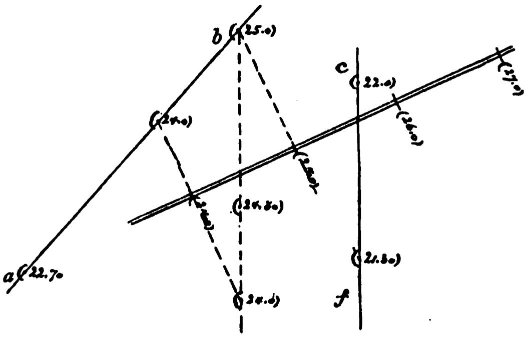


19. Problem.—Let it be required **to determine the position of a plane which shall pass through a given right line, and be parallel to a second given right line.**

If through a point assumed upon the first right line, a right line be drawn parallel to the second, the plane of these two lines is the plane required.

Let *ab* (Fig. 11), be the right line through which the plane is to be passed, and be made parallel to the right line *cf*.

Fig. 11.



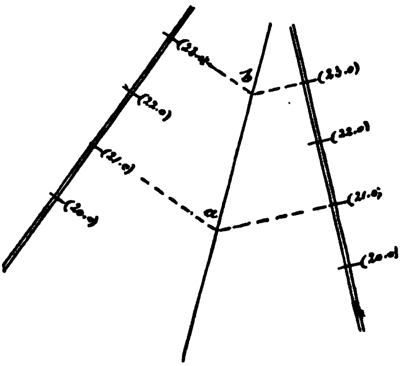
Take any point on the line *ab*, as *b* (25.0), and draw through it a line parallel to *cf*. (Art. 10.) Determine the plane of these two lines by drawing the horizontals and constructing the scale of slope. (Art. 14.) The plane thus determined is the plane required.

20. Problem.—Let it be required **to find the intersection of two given planes.**

If the planes intersect, horizontals of the same reference will intersect, and the points of intersection of these horizontals will be points of the line required.

Let the scales of slope, shown in Fig. 12, represent the given planes. Produce the horizontals (23.0) until they intersect; the point *b* is one point of the line of intersection. Do the same with the horizontals (21.0); the point *a* is another point of the line of intersection. Since the planes intersect in a right line, the line drawn through the points *a* and *b* is the line required.

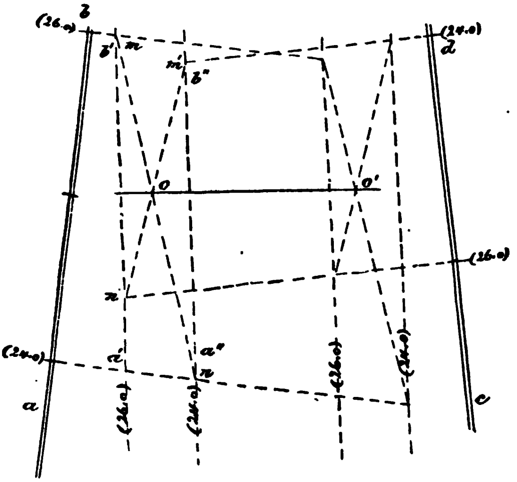
Fig. 12.



If the horizontals of the planes are parallel, or nearly so, the construction just used is not practicable. The method employed in this case is to use auxiliary planes intersecting the given planes. Then finding the intersections of the auxiliary planes with the given planes, determine points common to the intersection of the given planes.

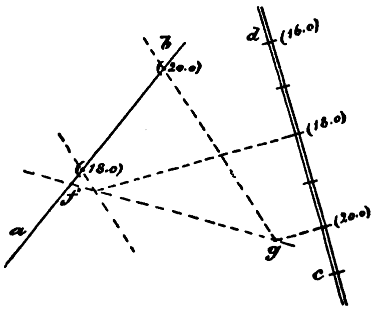
To illustrate this method, let *ab* and *cd* be the scales of slope of the given planes, (Fig. 13). Draw any two parallel lines, as *a'b'*, *a''b''*, and consider them to be horizontals of a plane, their references being (24.0 and (26.0) respectively. The intersection of this auxiliary plane with the plane *ab* is the line *mn*, and with the plane *cd*, is *m'n'*. These two lines intersect at *o*, a point common to the three planes; it is therefore one point of the line of intersection. In a similar manner the point *o'* is determined. The right line drawn through the points *o* and *o'* is the line of intersection of the two planes.

Fig. 13.



If the horizontals of the two planes had been parallel, one point would have been sufficient.

Fig. 14.



21. Problem.—Let it be required **to find the point in which a given right line pierces a given plane.**

Pass a plane through the given line and find its intersection with the given plane. The point of intersection of the line of intersection of the planes and the given right line is the point required.

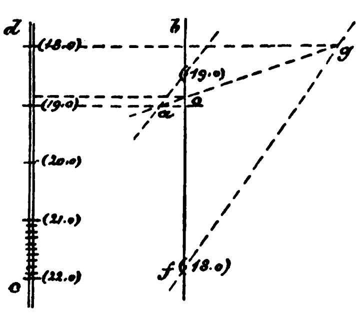
Let *ab* and *cd* (Fig. 14), be the given right line and plane. Through any two points of the line *ab*, as (18.0) and (20.0), draw two parallel right lines, and take them to be horizontals of the auxiliary plane. Find the intersection, *fg*, of the auxiliary plane with the given plane. Produce this line, if necessary, and where it cuts the line *ab* is the point in which the line pierces the given plane.

22. Problem.—Let it be required **to draw through a given point, a right line perpendicular to a given plane, and find the length of the line between the given point and the plane.**

The projection of the line will pass through the projection of the given point, and will be parallel to the scale of slope of the plane. This determines its projection.

Its slope is the complement of that of the plane. Knowing the slope and the projection, the line is fully determined. The length required is the hypothenuse of a right-angled triangle whose base is the distance between the projections of the given point and of the point where the line pierces the plane, and its perpendicular is the difference of references of these points.

Fig. 15.



Let *cd* (Fig. 15), be the given plane, and *f* the given point. Through *f* draw a right line parallel to *cd*; this will be the projection of the perpendicular. Knowing the slope of the plane *cd*, determine a second point, as (19.0). The two points determined, fix the line *bd*. Draw through two of its points parallel lines, as (18.0) and (19.0), and consider these the horizontals of an auxiliary plane. The point *o* is the projection of the point where the line pierces the plane. Through it draw a horizontal, and determine its reference. All the data have been determined, and the rest of the problem may now be solved.

CURVED AND IRREGULAR SURFACES.

23. Curved Surfaces.—Curved surfaces of simple geometrical construction are easily represented by the method of one-plane descriptive.

A cone is represented by its vertex and a horizontal section; a cylinder, by its axis and a horizontal section; a sphere by its centre and a horizontal section through its centre, etc.

In fortification drawing the curved surfaces mostly represented are those of the surface of the ground. This surface is always more or less undulating, in one place raised up above the general surface, in another depressed below this surface, etc. A method which will show to the eye the changes in elevation and the shape of the surface is the one required.

The method of representing oblique planes by horizontal lines is the one used to represent these irregular surfaces, and gives satisfactory results. The irregular surface is intersected by a series of equidistant horizontal planes, cutting the surface in curved lines which are horizontal, and which are called contour lines, or simply **contours.**

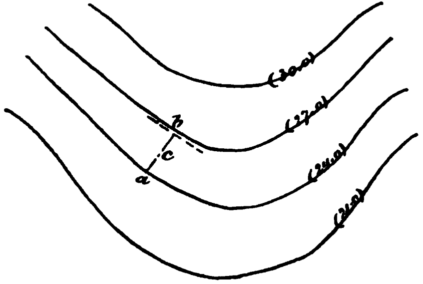
Since these lines are horizontal, a single reference for each one is all that is needed to fix them in position when their projections are given.

The nearer the horizontal planes are taken to each other, or the greater the number of them used, the more accurate will be the representation of the irregular surface.

For the purposes of construction, it is necessary to know how points and lines of irregular surfaces, lying between contours and not represented upon the drawing, may be obtained. It is supposed that the portion of an irregular surface between two contour lines does not sensibly differ from the portion of a warped surface, generated by moving a right line touching both the contours, and normal to the upper one. Knowing how to obtain any one of these elements, it will always be easy to find the reference of a point between the contours, when its projection is given; or to find the projection, when the reference is known. Let *c* be the projection of a point, lying between two contours (24.0) and (27.0, upon a surface given by the contours (21.0), (24.0), etc. (Fig. 16). Let it be required to find the reference of the point *c*.

Since the projection is that of a point upon the surface, and is between the contours (24.0) and (27.0), the reference of the point is between these numbers. Since it is a point upon the surface, its projection must lie upon the right line element passing through the point. Through *c* draw the right line *ab* perpendicular to the contour (27.0). The projection and the references of two of its points being given, the line is determined. From the proportion $ac : ab :: x : 3'$, the difference of reference to be added to (24.0), to give the reference of *c*, is obtained. A similar process will give the projection when the reference is known, and when the right line element is given. Finding any number of points of the same reference, and connecting them by a line, a contour of any given reference may be obtained.

Fig. 16.



24. Problem.—Let it be required **to find the intersection of a given irregular surface by a given plane.**

The horizontals of the given plane and the contours of the surface having the same references must intersect. These points of intersection are points common to the plane and surface. Connect them by a line, and it will be the line of intersection required.

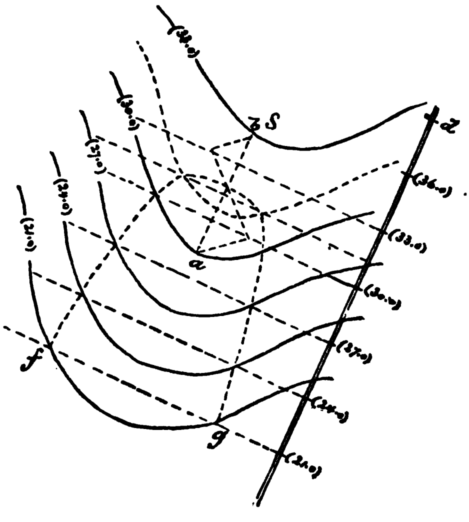
Let S be an irregular surface given by its contours (21.0), (24.0), etc., and *cd* the scale of slope of the given plane (Fig. 17).

Produce the horizontal (21.0) of the plane until it intersects the contour (21.0) of the surface. Do the same for the other horizontals. The line traced through *f* and *g* and other points of intersection is the line required.

If a horizontal does not intersect a corresponding contour, there is no point of intersection of that reference upon the drawing.

If intermediate points, other than those obtained, are required, an intermediate contour of the required reference may be constructed and its intersections by the corresponding horizontal of the plane obtained; or a right line element may be constructed, and the point in which it is cut by the plane determined.

Fig. 17.



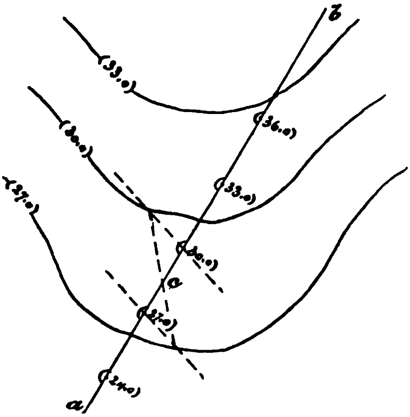
This method may be used to find the curve of intersection of any two surfaces which intersect.

25. Problem.—Let it be required **to find the point where a right line pierces a given surface.**

Through the given right line pass an auxiliary plane, and find the intersection of this plane with the surface. The point in which the given right line crosses the line cut out of the surface by the auxiliary plane, will be the point required.

Let (24.0), (27.0), (30.0), etc., be the horizontals of the given surface, and *ab* the given right line (Fig. 18).

Fig. 18.



Through (27.0) and (30.0) of *ab*, draw two parallel lines and take them to be horizontals of an auxiliary plane. The point, *c*, where the right line intersects the line cut out of the surface, is the point required. In the figure, to avoid confusing the drawing, only two points of the curve of intersection are found. Where great accuracy is required, more points should be determined and the curve fully constructed.

TANGENT PLANES.

26. Problem.—Let it be required **to pass a plane through a given point upon an irregular surface and tangent to the surface.**

There are two cases: one, in which the point lies upon one of the contours; and the other, where the point lies upon the surface between two of the given contours.

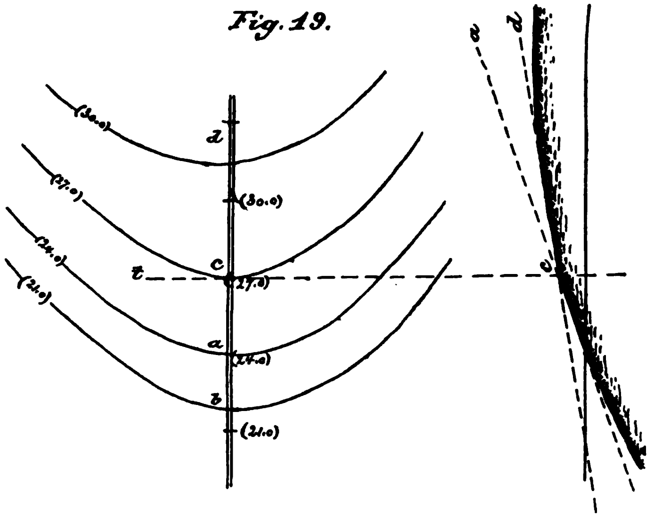
First case. The point taken upon a contour. The plane passing through this point containing the tangent line to the contour at that point and the right line element of the surface at that point, is a tangent plane.

Let *c* (Fig. 19) be the point upon the contour (24.0) through which a plane is to be drawn tangent to the given surface.

Through *c* draw a right line tangent to the contour line at that point. This will be one line of the required plane. Through the same point, draw the right line element of the surface between contours (24.0) and (27.0), and this will be a line of the tangent plane. The scale of slope of the plane of these lines will be perpendicular to the tangent; the references of the extremities of the right line element are respectively (24.0) and (27.0). From these data the scale of slope may be constructed.

Suppose this tangent plane to be revolved about the tangent line, *c t*, as an axis, until the right line element through

Fig. 19.



c and *d* lies in the plane. This plane in its new position will be a tangent plane to the surface at the point *c*. Hence, all planes lying between the planes *ac* and *cd* (section, Fig. 19) and passing through *c*, will fulfill the conditions of touching this surface only at one point, immediately around the point of contact.

Second case. The point of tangency not taken upon a contour line. It will be an easy matter to construct a contour line which shall pass through the point, and then pass a tangent plane as just described. An approximate method generally used for this case is, to construct the right line element passing through the point, and through the point draw a horizontal parallel to the tangent at the upper extremity of the element; the plane of these two lines is taken to be the tangent plane required.

Note.—The surface of the ground with respect to the plane of reference may be all convex in the vicinity of the point of contact, it may be concave, or it may be partly convex and partly concave.

In the first case, the tangent plane lies entirely above all ground immediately around the point of contact; in the second case, it lies entirely below this ground; and in the third case, it lies partly above and partly below the surface of the ground to which it has been passed tangent.

27. Problem. — Let it be required **to pass a plane through a given right line and tangent to a given surface.**

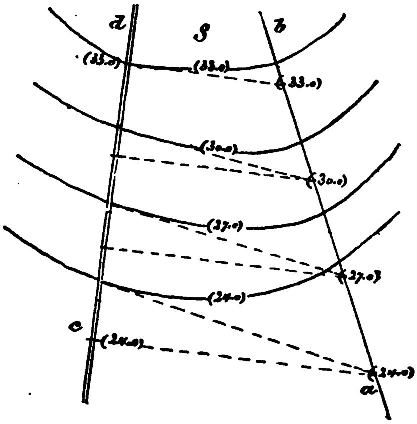
If a plane be passed through the given line intersecting the surface, and from any point on this line a tangent line be drawn to the line of the surface cut out by this plane, the plane of the tangent line and given line will be the tangent plane required.

Suppose a tangent plane to have been constructed, and suppose a horizontal plane passed through the point of tangency. The horizontal plane would cut from the surface a contour line, and from the tangent plane a right line tangent to this contour.

If, therefore, right lines be drawn from points of the given line and tangent to the contour lines of the same reference, one of these tangent lines thus drawn must necessarily belong to a tangent plane passing through the line and tangent to the surface. Finding this tangent line, the plane of this line and the given right line will be the tangent plane required.

Let S be the surface given by its contour lines, (27.0), (27.0), etc. (Fig. 20), and *ab* the given right line. Through the points (24.0), (27.0), etc., of the right line, *ab*, draw right lines tangent to the contour lines with the same reference. The tangent line which makes the least angle with the descending portion of the given line is the tangent line sought. For, let the tangent drawn through (33.0) be that one which makes the least angle. Construct the scale of slope, *cd*, of the plane of the tangent line (33.0) and the given line *ab*. Through the points (30.0), (27.0), (24.0), etc., of the given line draw the horizontals of this plane, *cd*. It will be seen that all these horizontals, thus drawn, fall exterior to, and do not intersect, the corresponding contour lines of the surface; that is, the plane, *cd*, lies above these contour lines. Suppose the tangent line through the point (30.0) to be taken, and the plane of this line and the given line to be constructed. It will be seen that the horizontal (33.0) of this plane would intersect the contour of the same reference; that is, the plane of the given line and the tangent drawn through (30.0) would intersect the surface, and not lie above it nor be tangent to it. Hence, the line making the least angle is the line sought, and the plane *cd* is the tangent plane required.

Fig. 20.



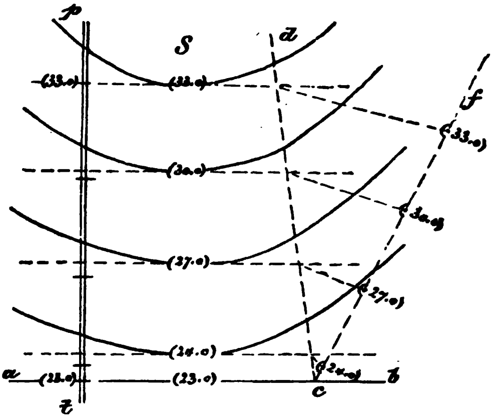
28. Problem.—Let it be required **to pass a plane through a given right line tangent to a given surface when the right line is horizontal.**

The method just employed cannot be used in this case, and the general method has to be taken.

Right lines are drawn parallel to the given right line and tangent to the contour lines of the given surface. These right lines form the surface of a cylinder. A plane is passed through the given right line and tangent to the cylinder; it will be the plane required.

Let S (Fig. 21) be the surface given by the contour lines, (24.0), (27.0), etc., and *ab* the given right line parallel to the plane of reference. The dotted lines tangent to the contour lines are the projection of the elements of the cylinder.

Fig. 21.



Assume any point upon the given right line *ab*, as *c*, and through it pass a vertical plane, as *cd*, intersecting the cylinder. This plane cuts a line from the cylinder. Through *c* draw a tangent line to this line of intersection; the plane of this tangent line and the given line is the plane required.

The line of intersection of the plane and surface is projected in the trace of the plane *cd*. To find the tangent line to this curve, draw any arbitrary line, as *cf*, and construct an assumed scale of slope. Through the points of reference (24.0), (27.0), etc., draw right lines to the points where the elements of the cylinder intersect the trace of the vertical plane *cd*. By a similar course of reasoning as that given in the last article, the right line which makes the least angle with the line *cf* determines the point of tangency. This point of tangency in the figure is found to be at the point (33.0) of the line projected in *cd*. Since the two points, (33.0) and (23.0), are known and the projection given, the line is fully determined. Construct the scale of slope of the plane of this line and the given line, and it will be the scale of slope of the required tangent plane.

Note.—When the line is nearly horizontal, it will ordinarily not be practicable to draw the tangents to the contours within the limits of the drawing. When this is the case another method is used to solve the problem. It is, to take a point upon the given line as the vertex of a cone and construct a cone tangent to the surface. Then, pass a plane through the line tangent to the cone, and the plane thus drawn will be tangent to the surface.

If the given line pierces the surface, or lies below it, the problem cannot be solved.

29. Problem.—Let it be required **to pass a plane through a point exterior to a double curved surface and tangent to the surface.**

The method has been described in the foregoing note. A cone, tangent to the surface, with the given point as its vertex, is constructed. Any plane passed tangent to this cone will pass through the given point and will be tangent to the surface.

Suppose such a cone constructed. Any horizontal plane will intersect the cone in a line. A straight line drawn tangent to this line of intersection will be a horizontal of a tangent plane. A horizontal and the given point determine the plane.

30. Problem.—Let it be required **to find the line of in-**

tersection cut from a tangent cone by a horizontal plane.

To construct the elements of a cone which shall be tangent to a given surface, suppose such a cone constructed. Any vertical plane passed through the vertex will cut from the surface a line, and from the cone a right line element tangent to the line of intersection.

Hence, through the vertex of the cone draw right lines intersecting the surface, these will be projections of the elements of the cone. The vertex of the cone is given, therefore the reference of one point is known. It is only necessary to obtain the reference of another point to fix the position of any one element. To do this, let the projection of the element be considered as the trace of a vertical plane. It will be the projection of the element of the cone and also the projection of the line of intersection to which it is tangent. The point of tangency is found by the use of an arbitrary line as shown in Art. 25, and thus a second point of the element is determined, which fixes the line. As many elements as may be required are determined, and the whole will represent a cone tangent to the surface.

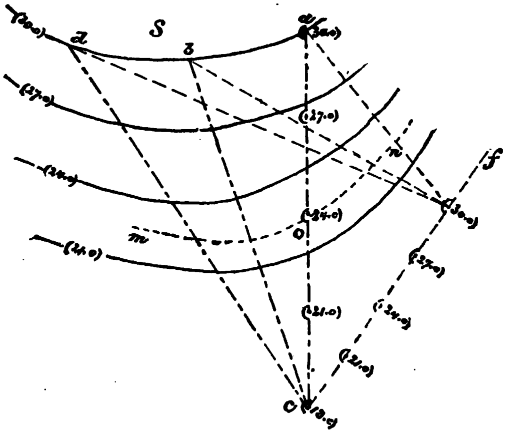
The intersection of this tangent cone by a horizontal plane is found by the method used to find the intersection of surfaces by a plane.

Let S (Fig. 22) be the given surface, and *ca*, *cb*, *cd*, etc., the elements of a tangent cone. Let *a*, *b*, *d*, etc., be the points of tangency of these elements determined by the arbitrary right line *cf*.

The scales of slope of *ca*, *cb*, *cd*, etc., may be constructed. Let this cone be intersected by any horizontal plane as that through (24.0). Through the points of each of the lines having the same reference draw a line, as *m*, *o*, *n*; this will be the line of intersection of the cone by the plane (24.0).

The scales of slope need not be constructed to obtain these points, *m*, *o*, *n*, of the line of intersection, when the arbitrary line is on the drawing. It is only necessary to take the point of the arbitrary line whose reference is the same as that of the horizontal plane, and draw through it lines parallel to those used to determine the points of tangency. The points in which these lines intersect the projections of the elements will give points of the line of intersection of the plane and cone.

Fig. 22.



Any right line drawn tangent to this curve *m*, *o*, *n*, will be a horizontal line, and such a line, with the point *c*, would fix the position of a tangent plane to the surface.

Since an infinite number of tangent lines can be drawn to this line of intersection, it follows that from a point exterior to a double curved surface, or an irregular surface of convex form, an infinite number of tangent planes may be passed.

31. Problem.—Let it be required, **having given a limited portion of surface and a point above it, to pass a plane through this point which shall lie entirely above, and be tangent to the surface.**

Suppose the surface enveloped by a tangent cone whose vertex is the given point, any plane passed tangent to this cone will be tangent to the surface. If the tangent plane be passed so as to lie above all the elements of the cone, it will lie above the given surface and be the tangent plane required.

The practical application of this problem is found in planning a fortification, where a salient is taken some distance above its projection upon the surface, but considerably lower than the surface of the ground within cannon range. The problem, in this case, is to determine a plane, or planes, passing through this salient, in which the faces of the work may lie, and which plane, or planes, shall lie above the surface of the ground within given limits.

Let *c* (24.0) (Fig. 23), be the given point, and the limited surface be the ground given by its contours (30.0), (27.0), etc., contained within the arc **A B C**, and the radii **A***c* and **C***c*.

Envelop this given surface by a tangent cone whose vertex is *c*. Intersect this cone by any horizontal plane, as (27.0), and let *m*, *o*, *n* be the line of intersection cut from the tangent cone by this plane.

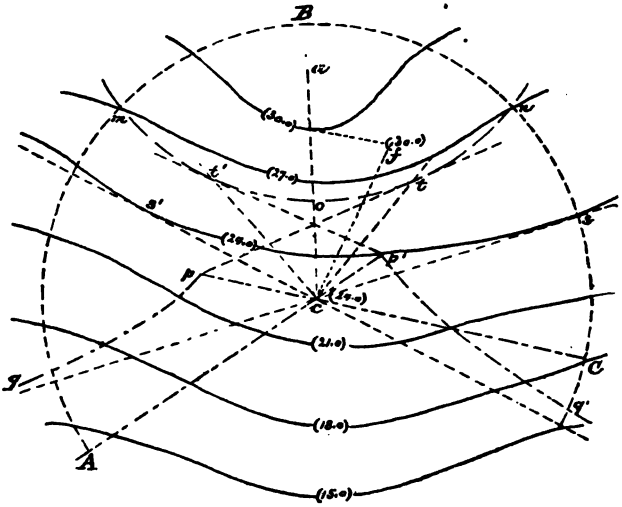
Any right line drawn tangent to this curve will, with the given point *c*, fix the position of a tangent plane to the cone. The condition is that this plane must pass above every point of the given limited surface.

Through *c* pass a horizontal plane, and it will cut from the cone two horizontal elements; one, tangent to the contour (24.0) at *s*′, and the other tangent to, or touching this contour at *s*.

The surface of the ground slopes in an upward direction from *c* to the contour (30.0); and, downward from *c* to the contour (15.0). All the elements of the tangent cone lying within the angles *Acs*′ and *Ccs* lie below this horizontal plane through *c*.

Suppose the elements lying within these angles to be produced upward through the vertex *c*, they would form portions of an upper nappe of the tangent cone. The horizontal plane (27.0), which cuts from the tangent cone the line *m*, *o*, *n*, would cut these elements of the upper nappe. Find the intersection of these elements of the upper nappe and this horizontal plane by finding upon the limiting elements *cC*, and *cA*, and other elements of the nappe, the points whose reference are (27.0). Let *p* be the point on the element *cC* thus determined. It will be one point of the curve, in the angle *Acs'* cut from the nappe. Find other points in this angle and join them by a line, as *pq*. This line of intersection constantly approaches, in projection, the horizontal element *cs*, produced through *c*.

Fig. 23.



This same plane cuts the upper nappe in a corresponding line *p'q'* in the angle *Ccs*.

It is plain that a tangent plane, to pass through *c* and lie above all the surface, must pass above all the elements of the tangent line in the angle *sCs'*, and below the elements of the nappes in the angles *Acs'* and *Ccs*.

Through the point *p*, let a tangent line, *pt*, be drawn to the curve *m*, *o*, *n*. It is a horizontal and a tangent line, and with *c* will fix the position of a tangent plane. This tangent plane from its construction lies above all the elements of the tangent cone in the angle *scs'*, excepting the element *ct* which it contains; it lies below all the elements of the upper nappe in the angle *Acs'*, excepting the element *pc* which it contains. It therefore lies above all points of the given surface.

A similar reasoning shows that the plane passed through *c* and the tangent *p't'*, is a tangent plane, and passes above every point of the given surface.

And finally, that any right line drawn tangent to the curve *m*, *o*, *n*, between the points *t* and *t'*, will with the point *c*, fix the position of a tangent plane lying above every point of the given surface. These points *t* and *t'* are therefore the limits within which tangent planes through *c* can be drawn to this surface, and lie entirely above every part of it.

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